End of study project:

STUDY OF ENCAPSULATION AND TRANSPORT OF 3DTV BY SATELLITE

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Student: Tania Monreal Barbarin

Company supervisor: Cedric LeGuern

University tutor: Mikel Sagües

Public University of Navarra

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1. ABBREVIATIONS

16APSK	16-ary Amplitude and Phase Shift Keying
32APSK	32-ary Amplitude and Phase Shift Keying
8PSK	8-ary Phase Shift Keying
ACM	Adaptive Coding and Modulation
AFC	Adaptation Field Control
ASI	Asynchronous Serial Interface
ATM	Asynchronous Transfer Mode
AU	Access Units
BB	Baseband
BBF	Base Band Former
BBHEADER	Base-Band Header
BCH	Bose-Chaudhuri-Hocquenghem multiple error correction binary block code
BER	Bit Error Ratio
BS	Broadcast Service
BSS	Broadcast Satellite Service
CBR	Constant Bit Rate
CBR	Constant bit rate
CCM	Constant Coding and Modulation
CENELEC	European Committee for Electrotechnical Standardization
CNI	Carrier to Noise plus Interference ratio
CRC	Cyclic Redundancy Check
D	Destination Address Absent
DF	Data Field
DNP	Deleted Null Packets
DSM-CC	Digital storage media command and control
DSNG	Digital Satellite News Gathering
DTH	Direct To Home
DTH	Direct-to-home
DTS	Decode Time Stamp
DVB	Digital Video Broadcasting project
DVB-C2	Digital Video Broadcasting- Cable
DVB-H	Digital Video Broadcasting- Terrestrial
DVB-S	DVB System for satellite broadcasting
DVB-S2	Second generation DVB System for satellite broadcasting and unicasting
DVB-SH	Digital Video Broadcasting- Satellite services to Handhelds
DVB-T2	Digital Video Broadcasting- Terrestrial
EBU	European Broadcasting Union
EI	Error Indicator
ELG	European Launching Group
ERIP	Equivalent isotropically radiated power
ES	elementary streams
ESCR	Elementary Stream Clock Reference
FDM	Frequency Division Multiplex
FEC	Forward Error Correction
FIFO	First In First Out
Frag ID	Fragmentation Identifier
FSS	Fixed Satellite Service
GS	Generic Stream

GUI	Graphical user interface
HDTV	High Definition TeleVision
IRD	Integrated Receiver Decoders
ISCR	Input Stream Clock Reference
ISI	Input Stream Identifier
ISSY	Input Stream SYnchronizer
ISSYI	Input Stream SYnchronizer Indicator
ITU	International Telecommunications Union
LDPC	Low Density Parity Check (codes)
LLC	Logical Link Control
LNB	Low Noise Block
LSB	Least Significant Bit
MIS	Multiple Input Stream
ModCod	Modulation and Coding
MPE	Multi-Protocol Encapsulation
MPEG	Moving Pictures Experts Group
MPEG-2 TS	MPEG-2 Transport Stream
MPTS	Multiple Programme Transport Stream
MSB	Most Significant Bit
MVC	Multi-View Coding
MVD	Multiview Video plus Depth
NP	Null Packets
NPD	Null-Packet Deletion
PES	Packetized Elementary Stream
PID	Packet IDentifier
PL	Physical Layer
PS	Program Stream
PSI	Program Specific Information
PSK	Phase Shift Keying
PTS	Presentation Time Stamp
PUSI	payload unit start indicator
QEF	Quasi-Error-Free
QoS	Quality of Service
QPSK	Quaternary Phase Shift Keying
RO	Roll-Off
RS	Reed Solomon
SAOC	Spatial and Audio Object Coding
SDTV	Standard Definition TeleVision
SIS	Single Input Stream
SNAP	Sub-Network Attachment Point
SNDU	Sub Network Data Units
SOF	Start Of Frame
SPTS	Single Programme Transport Stream
STB	Set-top box
TDM	Time Division Multiplex
TS	Transport Stream
TS	Transport Stream
TSDT	Transport Stream Descriptor Table
ULE	Unidirectional lightweight encapsulation
UP	User Packet
UPL	User Packet Length
VBR	Variable bit rate
WFS	Wave Field Synthesis

2. FIGURES

3. INTRODUCTION

This document is a summary of the end of study project “**STUDY OF ENCAPSULATION AND TRANSPORT OF 3DTV BY SATELLITE**” to achieve the degree of Ingeniero de Telecomunicación at the Public University of Navarra.

The project was developed in EADS ASTRIUM Toulouse in the framework of the MUSCADE project with the latest technologies in 3DTV.

Currently most of the research in satellite broadcasting field is focused in 3DTV transmission as the following of HDTV. MUSCADE is a European project funded by the 7th Framework Program whose objective is to demonstrate a complete multiview 3DTV live chain over wireline, wireless and satellite networks.

This project aims to set up a satellite testbed to validate the 3D content format defined by MUSCADE in a emulated satellite environment.

The document’s first chapter describes the environment where the internship has taken place and a brief overview of the EADS Company.

After, a short description of the whole MUSCADE project can be found in section 5. This allows the reader to achieve a global vision of all the technological concepts involved in the project even if this internship is focused in satellite transmission.

Section 6 describes the internship development.

By means of conclusion, the new skills achieved, the knowledge applied and a professional and personal balance could be found at the end of this report.

4. COMPANY CONTEXT

4.1 EADS

The **European Aeronautic Defence and Space Company EADS** is a large European aerospace corporation. The company was created on July 10, 2000, through the merger of Germany's DaimlerChrysler Aerospace AG (DASA), France's Aerospatiale Matra and Spain's Construcciones Aeronáuticas SA (CASA). It is the leading aerospace company in Europe and the second worldwide. EADS is a global leader in aerospace and defence, developing and marketing civil and military aircraft, as well as missiles, space rockets, satellites, and related systems. They employ over 118,000 people on more than 70 production sites, mostly located in Germany, France, Great Britain and Spain. This group is divided into four branches, as we can see on the diagram below.

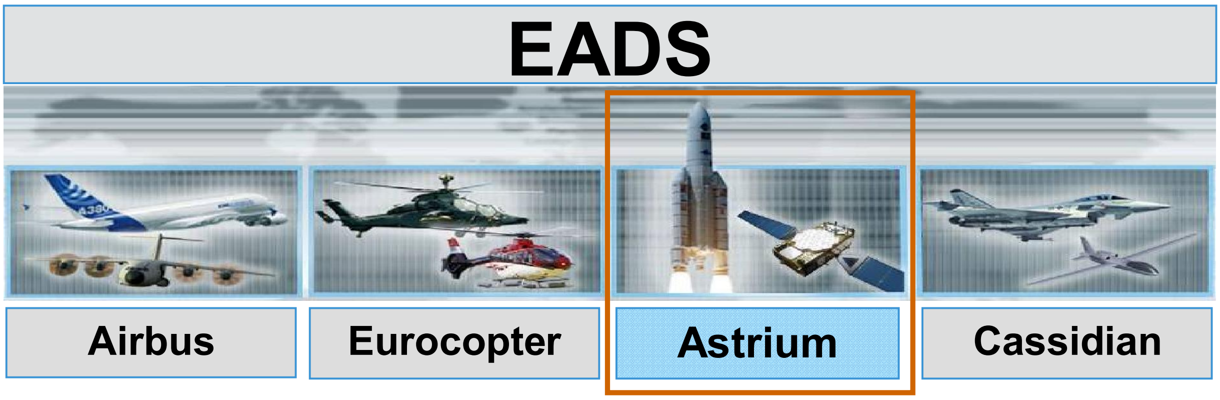


Figure 1: Astrium organization

- **The Airbus division gathers** both public and military aircraft manufacturing since Airbus absorbed the previous Airbus Military division in April 2009.
- **The Eurocopter division is** the world leader in civil and parapublic helicopters manufacturing.
- **Astrium** division adds the full range of competencies in the fields of launchers, manned spaceflight, satellites and ground systems as well as civil and military satellite based services.
- **Cassidian**: is the defense and security subsidiary of the EADS group and a major provider of global security solutions, lead system integration and aerial, land, naval and joint systems.

4.2 EADS ASTRIUM

EADS Astrium is an international player in the conception and manufacturing of telecommunication satellites, and also in the European programme satellite navigation system Galiléo. Astrium was created from the merger of two companies in June 2006: EADS Space Transportation and EADS Space Services. They employ over 15,000 people distributed as in the figure below

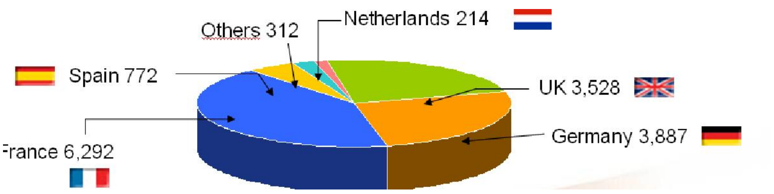


Figure 2: Employees per country

Its activities are articulated in 3 main domains:

Astrium is a global space industry leader, working in a complete range of launch capabilities, orbital systems and manned space activities, satellite systems, payloads and equipment for a wide range of civil and military applications. It is wholly owned by EADS as a part of the EADS group, and possesses locations all across Europe.

Figure 3: Astrium Locations across the world

Astrium controls all key technologies and techniques necessary to achieve the major space programmes, and provides comprehensive space solutions, adapted to the needs of customers.

4.3 ASTRIUM SATELLITES

Astrium satellites is a world leader in the design and manufacture of satellites systems. It is composed of 4 business divisions:

- **Earth Observation and Science:** Astrium primes for all European LEO (Low Earth orbiting) observation satellites, designs and manufactures a wide range of highly versatile platforms. There main activities are: meteorological forecasting, global environmental monitoring, reconnaissance for national security and peacekeeping. Astrium Satellites is also a major participant in programmes that aim at furthering our understanding of the Earth, the solar system and the wider universe.
- **Navigation:** Astrium plays a crucial role in the design and development of Galileo, the new Europe global navigation satellite system.
- **Subsystems, Equipments and Operations**: Astrium build Satellites key space equipment and subsystems technology areas, like (thermal management systems and components; guidance, navigation and control systems; antennas and reflectors, etc …)
- **Telecommunications:** Astrium provides a total satellite communications system capability in-house, from spacecraft and payload design, manufacture, test and launch to the complete ground control and communications infrastructure, in-orbit operation and services.

With more than 2000 employees, Toulouse is one of the most important sites of the EADS Astrium group. Astrium Toulouse is focused on Satellite subsystems for telecommunication and Navigation, earth observation and sciences.

Figure 4: Astrium Toulouse

4.3.1 ATB-3 department

The internship took place in the ATB-3 department (Telecom System Department) based in Toulouse. This department, managed by Bernard Laurent, is composed around 25 people.

The main role of ATB-3 is to take part in the development and promotion of new applications requiring the use of telecommunications satellites. This mission is designed to increase the number of users of satellite systems in order to make them more accessible. Also, ATB-3 contributes to the standardization of new satellite communication protocols as the DVB-RCS and DVBS2.

ATB-3 works with different partners & subcontractors as:

- Eutelsat
- SES Astra
- Inmarsat
- Avanti
- Hellasat
- Telesat
- Hispasat
- TAS
- Astrium Services
- UniS
- Speng
- HHI
- DLR
- …..

Its activities are divided into 5 themes detailed in the figure below:

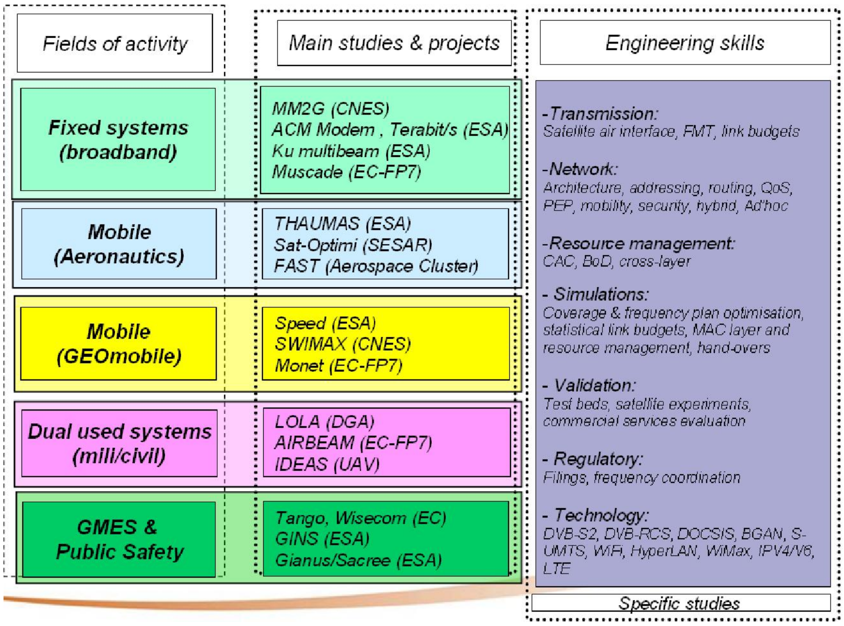


Figure 5: ATB-3 organisation

4.3.2 BLUE Lab

The BLUE Lab (Broadband Link Under Experiment Laboratory) is the validation laboratory of the ATB3 department. Its role is to develop and implement prototypes of the applications that have been entrusted to the ATB-3 department. The laboratory is divided in 2 parts: a wireless part dedicated to the projects involving the use of wireless technologies and more generically the network projects including hybrid systems; the second part is telecom-oriented and focuses on broadband applications. The laboratory possesses state-of-the-art equipments, including several satellite terminals as well as antennas.

Figure 6: BLUE lab antennas

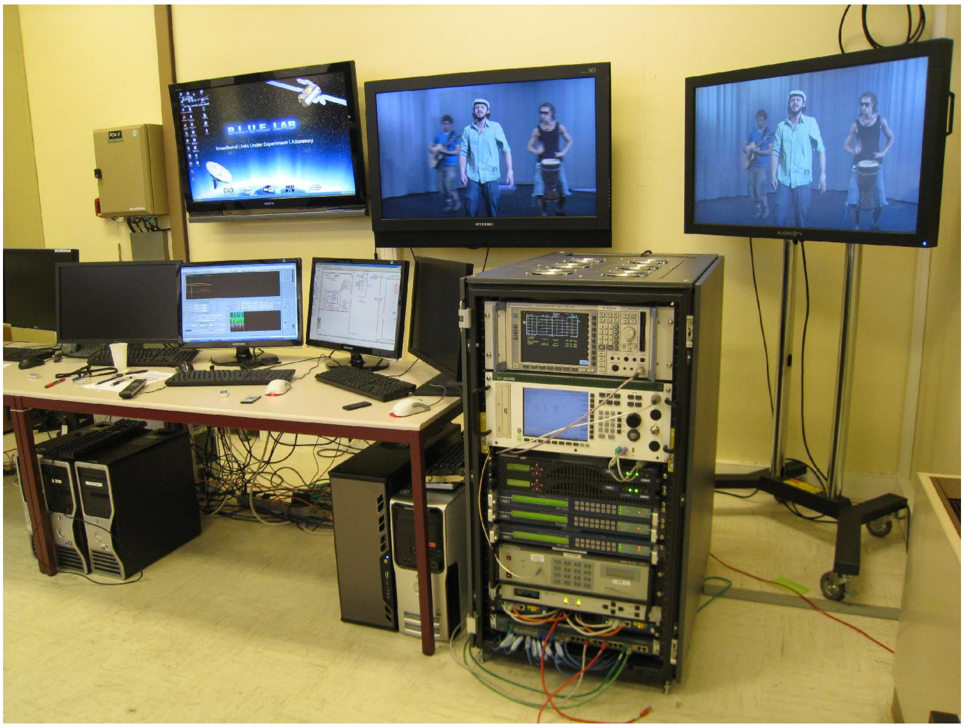


Figure 7: Blue Lab facilities

5. PROJECT CONTEXT: MUSCADE

MUSCADE (Multimedia Scalable 3D for Europe) is a European project, funded under the European Commission ICT 7th Framework Programme. MUSCADE aims at generating major innovations in the fields of 3DTV production equipment and tools, data representation, compression, transmission and rendering on various kinds of 3D displays. The final objective of MUSCADE is to demonstrate a complete multiview 3DTV live chain over wireline, wireless and satellite networks.

5.1 INTRODUCTION

The last decade has seen a revolution in the distribution of motion content: from analogue to digital and then from SDTV to HDTV. Both the delivery and the content creation industries exploited these advances, for the final benefit of consumers. Today, it is widely accepted that the next step is the evolution from HDTV to 3DTV, as indicated by the new industrial fora that appeared over the last years.

Combining strengths of twelve European partners, the objectives of the MUSCADE project cover the whole 3DTV chain.

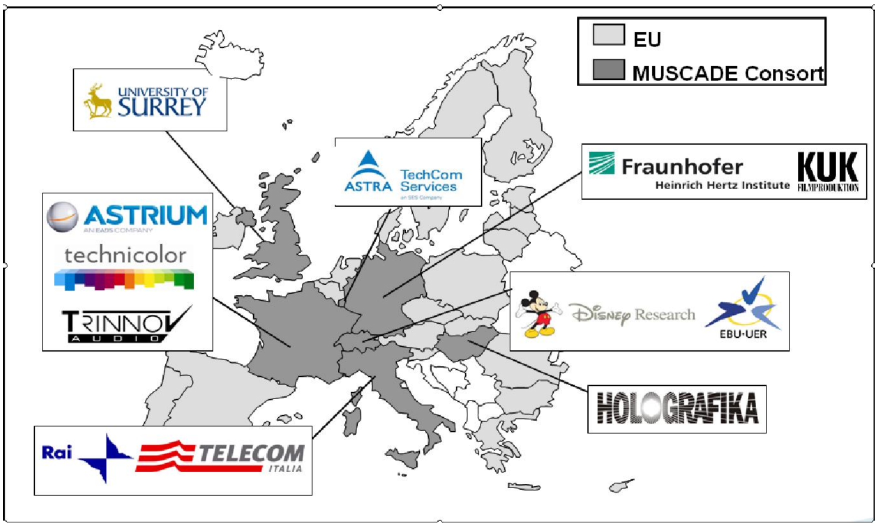


Figure 8: MUSCADE consortium

The project will define, develop, validate and evaluate the technological innovations in 3DTV capturing, data representation, compression, transmission and rendering required for a technically efficient and commercially successful 3DTV broadcast system. The MUSCADE reference system architecture is shown in Figure 9[1].

[1] Reference architecture and representation format Phase I. D 1.1.2

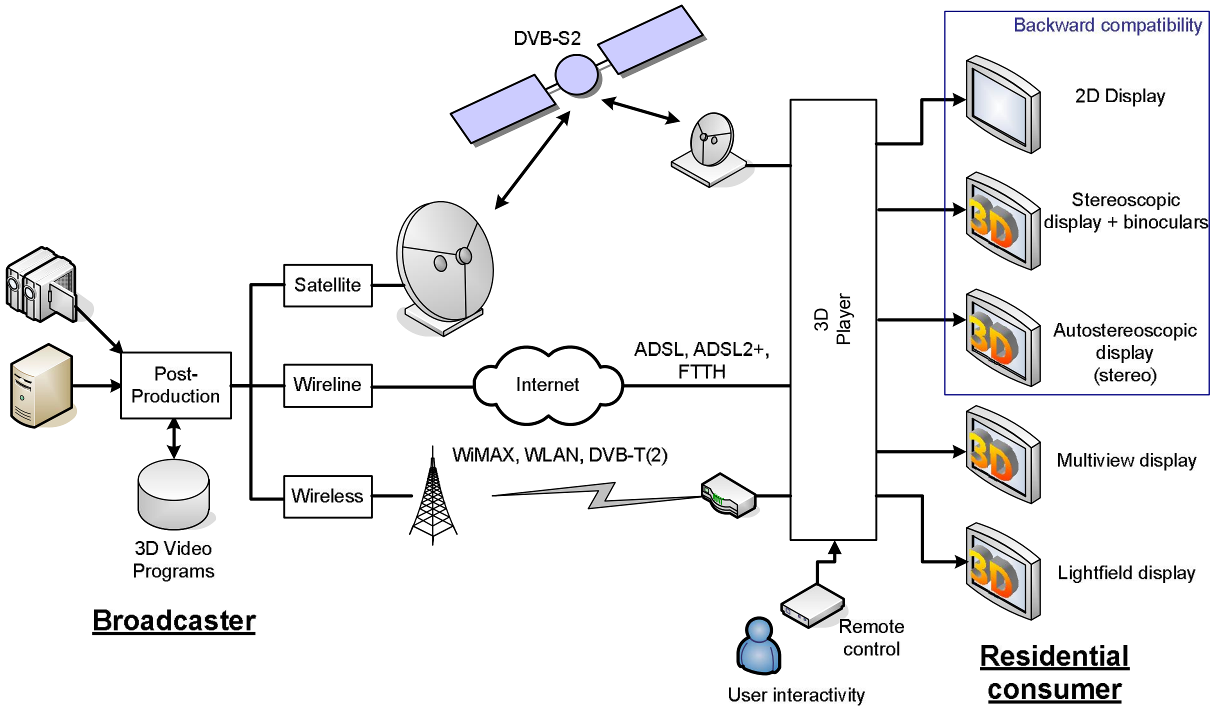


Figure 9: MUSCADE system architecture

5.2 VIDEO REPRESENTATION FORMAT AND SCALABLE CODING

First standardization on 3D video beyond standard stereo has been started in 2003, including video-plus-depth coding for 3D-TV in MPEG-C Part III. Multi-view coding (MPEG-MVC) was started in January 2006 and has been finalized in July 2008. A new initiative has been launched in July 2008 through the MPEG-3DV Adhoc group. None of the proposed solutions today are scalable in terms of network performances and display capabilities.

The system developed by the MUSCADE project will target a large range of displays: 2D, stereoscopic, multiview autostereoscopic and advanced lightfield displays. In the typical use case, one display is driven at a time. However, this doesn't mean that a specific video representation format will be generated according to the targeted display. Instead of that, the concept of view scalability will be part of the representation format of the 3D video.

MUSCADE has selected a MVD (Multiview Video plus Depth) based format: MVD4. It includes 4 HD views and 4 disparity maps, providing per-pixel depth information, as illustrated in Figure 10.

Figure 10: MVD4 video representation format

This format ensures efficient support of multiview autostereoscopic displays, as well as backward compatibility with stereoscopic and 2D displays. Indeed, a stereoscopic pair or a single HD view can easily be extracted by low complexity devices. Moreover, this format is compatible with the scalable transmission of 3D-TV, i.e. the adaptation of 3D content to propagation conditions, targeted by the MUSCADE project.

5.3 VIDEO CAPTURE AND POST PRODUCTION TECHNOLOGIES

To avoid undesired perception conflicts and well-known discomfort like eyestrain or visual fatigue, conventional stereo production as well as any other 3D production requires both, a careful set-up of the multiple camera views during shooting and an appropriate post-production process.

MUSCADE is developing an audio-visual acquisition system being able to capture two or more HD views (in 1080p25 in the first phase of the project) in conjunction with 3D sound. In contrast to the existing solutions, it will concentrate on the special requirements of 3D broadcast productions with its restricted post-production capabilities and its special needs for live broadcast. It includes an intelligent on-site assistance system for multiview and 3D sound acquisition providing all metadata needed for post-production and live broadcast in real-time.

The capture system of MUSCADE is based on a 4-camera set-up as illustrated in figure 11[2].

[2] Specification of 3D production workflow and interfaces Phase I. D 1.2.1

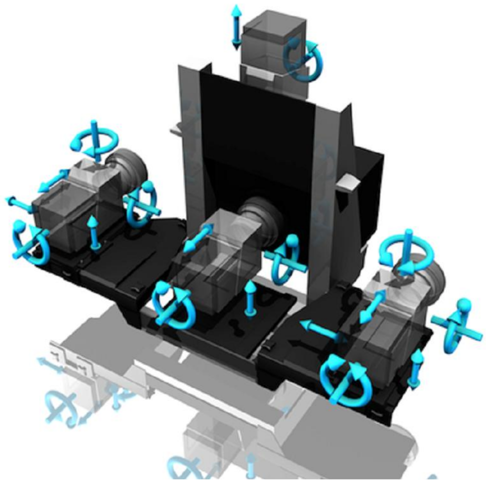


Figure 11: MUSCADE 4-camera rig

This camera set-up consists of an inner stereo pair that is compatible with conventional stereo production and enables backwards compatibility of the whole MUSCADE chain to standard stereo viewing. An outer wide-baseline stereo system provides all additional information for robust depth extraction and depth-image based rendering, allowing the support of a wide range of 3D displays. A special geometrical property of this 4-camera system is that it is calibrated such that all focal points are at one common straight line and that it follows a parallel stereo geometry. The related calibration, rigging and geometrical adjustment will be ensured by an image-based camera assistance system. The 4-camera system will be combined with a set of microphone arrays and individual microphones for recording separated sound sources and ambient acoustics. 3D video and audio acquisition will be properly synchronized and jointly calibrated. Calibration data will be sent as metadata in conjunction with rigging data and 3D stereo parameters from the camera assistance system.

This set of data (multiple synchronized audio and video streams plus metadata) forms the input for the MUSCADE 3D post-production system.

After generating the MVD sequences, the 3D video sequences are edited together with 3D sound. Apart from 3D sound editing and dubbing, this includes cutting, fading and blending of 3D sequences, mixing of different 3D sources like MVD4 and CGI data, graphical overlay and subtitle editing. The post-production process will be completed with final finishing and packaging of all data in a format that is suitable for coding and delivery.

5.4 ROBUST AND SCALABLE TRANSMISSION OF 3DTV[3]

After postproduction, the processed audio-visual 3D data is compressed into a suitable transmission format and encapsulated into appropriate transport streams. The packet streams are then fed into the

[3] Specification of 3D encoder and transmission channels Phase I. D 1.3.1

Audio visual 3D analysis for capturing and post-processing Phase I. D 1.2.2

transmission channels investigated in the project i.e. wireline (ADSL, ADSL2+, VDSL), wireless (DVB-T(2), WLAN, WiMAX) and satellite (DVB-S2) using both emulated and actual links.

The audio encoding algorithm is based on MPEG Surround and also supports Spatial Audio Object Coding (SAOC) by down mixing 8 audio objects (or object groups) maximum and producing related side information. AAC core codec is to be used for compressing downmixed signals.

The video encoding algorithm selected by MUSCADE is based on MVC, which is a natural solution for the coding of multiview videos. A first approach is to encode the views and the depth using two independent MVC encoders.

The carriage of MVC has been specified in an amendment of ITU-T Rec. H.222.0 | ISO/IEC 13818-1. This amendment enables the splitting of the MVC bit streams into multiple elementary streams (ES) with unique PIDs, each of them corresponding to individual views, and thus allowing for de-multiplexing on Transport Stream (TS) level, which is the pre-requisite for selective access to a certain set of views and unequal error protection mechanisms. Figure 13 illustrates the separation of MVC data into elementary streams.

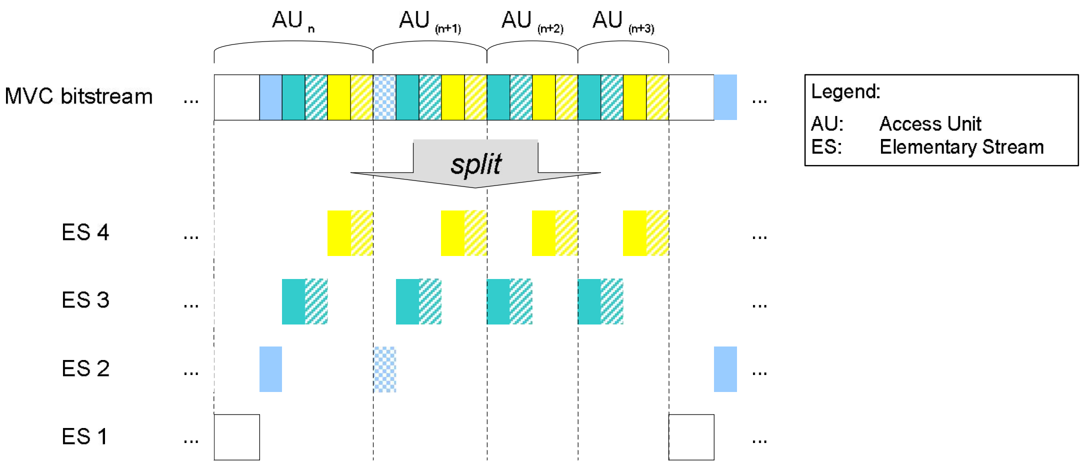


Figure 12: splitting an MVC bit stream into elementary streams

Since 3D-TV demand more system resources (e.g. transmission power, bandwidth) than conventional 2D video, optimum resource allocation schemes have to be developed in order to match the available resources and provide good quality 3D perception. The combined use of MVC coding and MVD4 is an efficient way to implement the scalable transmission of 3D-TV[4].

Scalability refers to the capability of dropping data fragments of a video bit-stream, which results when applied correctly in a new video bit-stream decode-able at lower quality (in terms of number of views in MUSCADE) at reduced data rate and reduced processing demands on the decoding platform. A multi-

[4] 3D encoding and transmission algorithms Phase I. D 1.3.2

view scalable bit-stream consists of a base layer (base view) and one or more enhancement layers (enhancement views), which enhances the decode-able 3D quality of the bit-stream.

The MUSCADE consortium defined 3 scalability levels, as shown in table 1.

		Preliminary bit rate estimation (1080p30, 8-bit depth encoding)
Stereoscopic pair		13 Mbps
ΔMVD2		7 Mbps
ΔMVD4		17 Mbps

Figure 13: MUSCADE scalability scheme

The first layer consists in a stereoscopic pair. The second layer consists in two depth maps, providing depth information for the layer 1 stereoscopic pair. The third layer includes the two outer views and the associated depth maps. This choice has been lead by the nature of the 3D displays targeted by MUSCADE and the capabilities of the networks addressed in MUSCADE.

A typical use case of the scalable transmission of a multi-layered 3D video over a satellite link using DVB-S2 is shown in Figure 14. The different quality layers are broadcasted in VCM (Variable Coding and Modulation) mode with different ModCod (Modulation and Coding) protection, enabling to make the 3D video displayable on every display with the best possible quality and depending on transmission conditions (clear sky or rainy conditions).

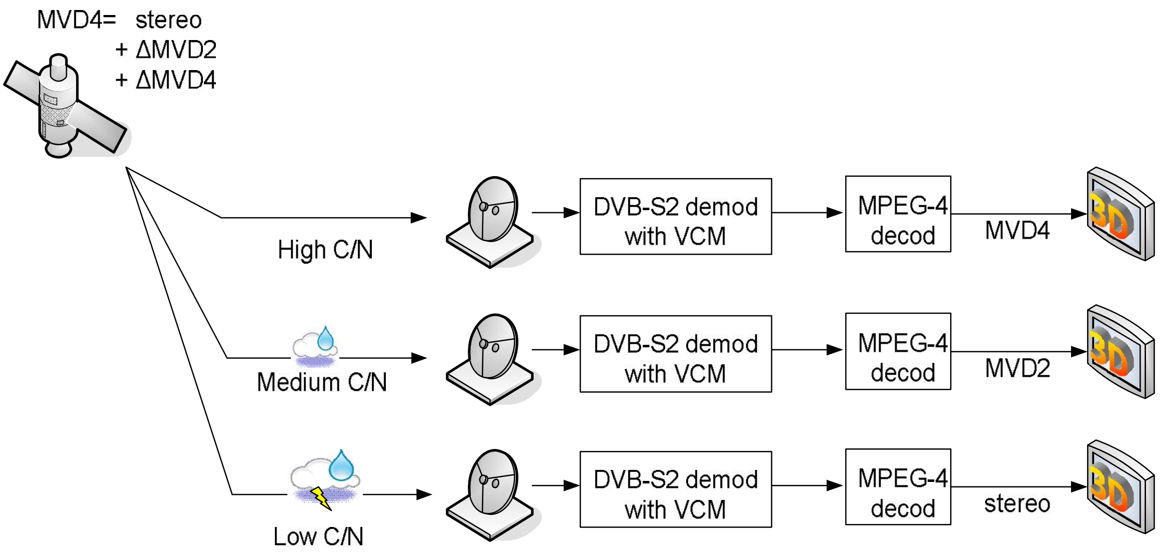


Figure 14: Scalable broadcasting of 3D video via satellite

The mapping between the different layers and ModCod is performed according to the quality layers to be transmitted: the base layer (stereo) is transmitted with a robust ModCod and the additional quality layers (ΔMVD2, ΔMVD4) are transmitted with a more spectral efficient ModCod. Such technique allows reducing the required satellite frequency resources at the expense of reduced link availability for high video quality layers (which can be counteracted by installing a larger antenna at the receiver side).

5.5 DISPLAY AGNOSTIC VIDEO RENDERING[5]

Various kinds of 3D ready displays for stereo are now available. LCDs with micro-polarisers with passive glasses and time sequential techniques with active glasses use two video streams for the two eyes.

Currently, several 3D “frame compatible” formats are proposed. However, these formats are not compatible with multi-view and light-field displays that are emerging. The display and technology dependent video formats make it very hard to transfer live 3D content from one 3D display to another one without losing serious amounts of information. Therefore, MUSCADE selected a video plus depth based format that is convenient for large range of displays. As explained in previous sections, the advantage of this type of format is the possibility to render the content from stereo (with glasses) display, to auto-stereoscopic and light field displays (without glasses). MUSCADE will implement a broadcast chain to demonstrate the display agnostic property of this format in real-time.

[5] Specification of A/V rendering and display adaptation Phase I. D 1.4.1

A/V rendering and display adaptation algorithms Phase I. D 1.4.2

For that purpose, MUSCADE is developing innovative rendering algorithms able of adapting the incoming 3D contents to any 3D display. A challenge consists in adapting 3D content to multiview displays and light-field displays, improving the received content by in-between view interpolation.

Another innovation of MUSCADE consists in providing to the user the possibility of adjusting the baseline in order to tune the depth perception and to reduce the eventual eye-strain.

Figures 15 and 16 present the overall diagram of the A/V stream player and the interactivity modules (redirecting the user to a 3D video interactive application platform[6], also developed in the frame of MUSCADE) connected to the various display technologies that are going to be addressed.

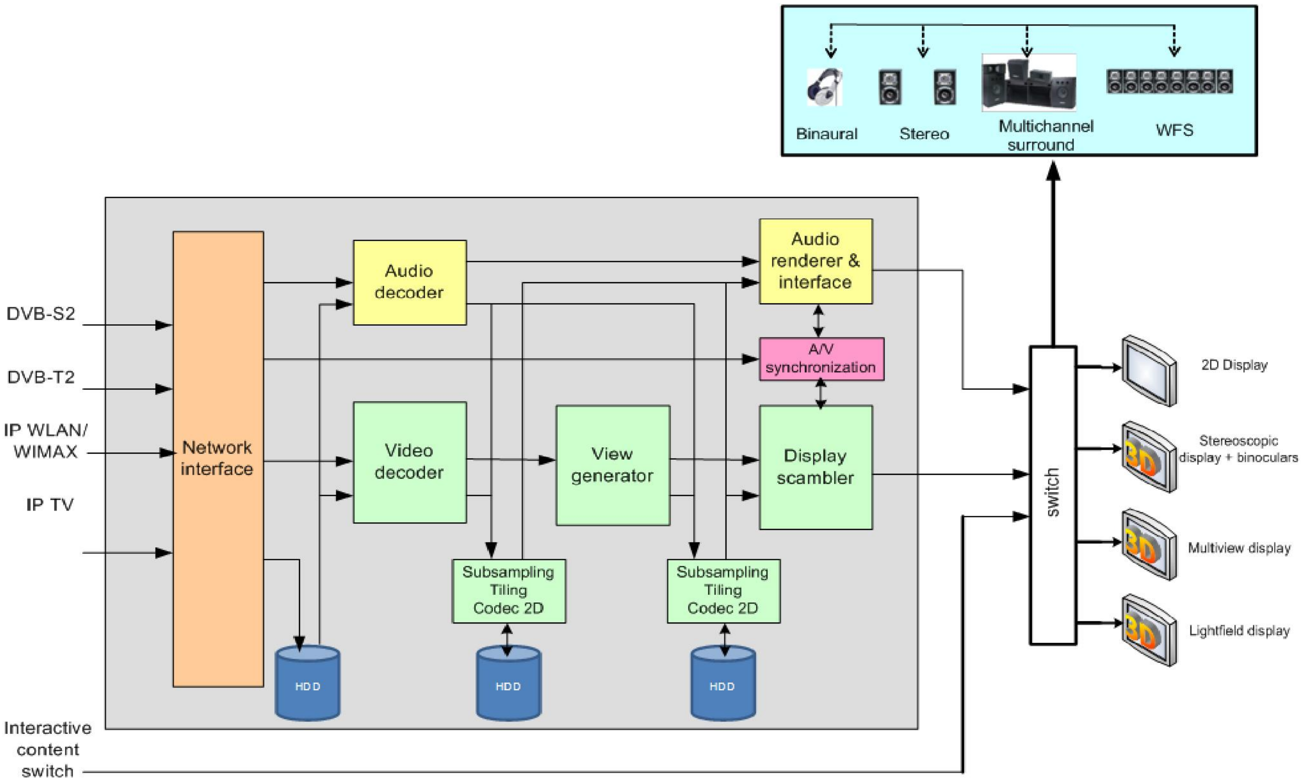


Figure 15: MUSCADE A/V player block diagram

The rendering module will be a PC based player ensuring the following functions:

- Network adaptation
- A/V decoding
- A/V synchronization
- A/V rendering

[6] 3D VIAP Specification and API Phase I. D 1.5.1

3D VIAP design Phase I. D 1.5.2

- A/V formatting for the various displays and loudspeakers

During the first phase of MUSCADE, real time rendering will only be performed for the 2D and 3D stereo cases. Taking into account the complexity of the light field display, a specific interface based on a Gigabit Ethernet connection will be set up to connect the player to the Lightfield adaptation system. The other displays will be connected either through DVI or HDMI interfaces

The audio rendering will be synchronized with video using the scene description in the A/V player and will drive a multichannel audio interface equipment connected to a set of loudspeaker rigs that could be Binaural, Stereo, Multichannel surround or Wave Field Synthesis (WFS).

The interactivity reference architecture described in figure 16 introduces a distinction between the interactive services domain and the home domain.

In the interactive services domain, three roles are identified: content provider, application platform provider and satellite network provider.

The content provider's responsibilities are to create A/V and interactive 3D content (in the production phase) and to interlink the two by inserting subtitles in the A/V stream (in postproduction). The latter process is referred to as synchronisation decoration as it decorates the A/V stream with information about which interactive content is associated to which A/V sequences.

The application platform provider is responsible for publishing and distributing the A/V and interactive content to the viewer using the 3D Video Interactive Application (VIA) platform. Content can be either pushed to the viewer by broadcast, or pulled by the viewer on request (Content on Demand).

The 3D Video Interactive Application (VIA) platform allows for the aggregation and syndication of platform services by the interactive TV content provider across different delivery mechanisms (such as DTH, IPT and mobile). It offers content providers horizontal services and standard interfaces facilitating the development and deployment of video interactive applications. The following horizontal services interfaces will be available for MUSCADE 3D interactive applications:

- user management – security, access control and account management
- application management – lifecycle of video interactive applications
- messaging – unified access to multiple message protocols and networks
- payments – payment transactions, wallet management and credit clearance

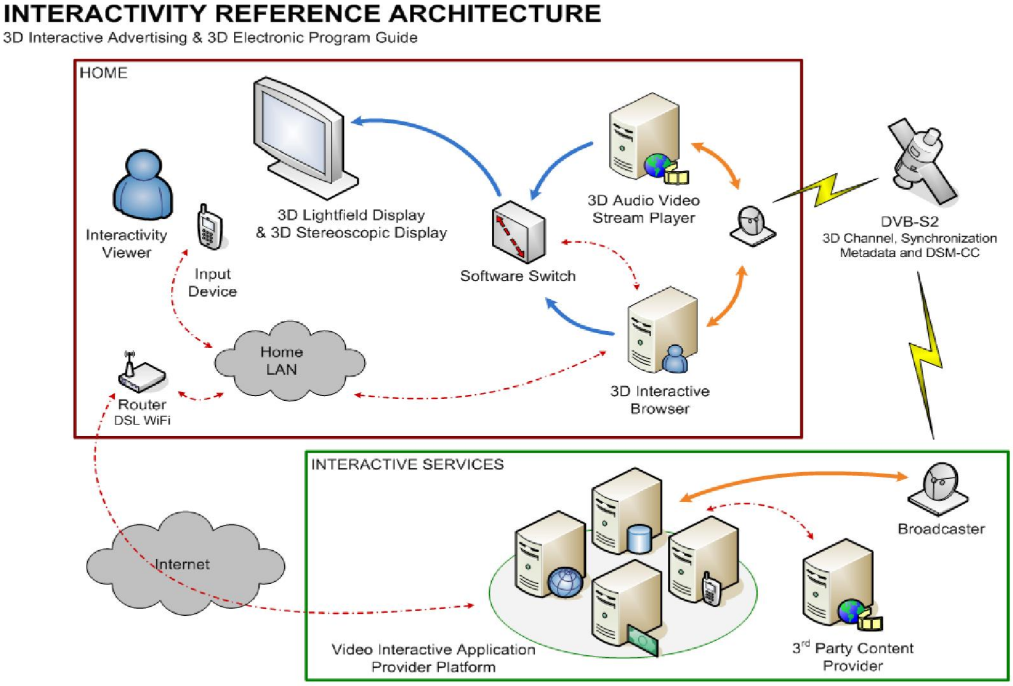


Figure 16: Interactivity architecture

6. INTERNSHIP DEVELOPMENT

6.1 DESCRIPTION AND OBJECTIVES

The end of study project has taken place in the BLUE Lab (Broadband Links Under Experiment LABoratory) of Astrium Toulouse. The aim of the project was to participate in setting-up a complete multi-view scalable 3DTV chain based on the algorithms and technologies developed in order to assess end-to-end performance over satellite network. In addition, it has been necessary to develop a monitoring and automation tool in Labview language.

The internship was divided in two main objectives. The first one was to take an active part in the definition and analyse of the different methods of encapsulation of TV data for the satellite channel (DVB-S2). To achieve this the following tasks were carried out:

- Study of the encapsulations methods for satellite broadcasting.
- Synthesis of the chosen solutions: state of the art “DVB review”

The second objective was to participate in the satellite testbed campaign through the following tasks:

- Setting up the testbed platform.
- Definition of metrics of testbed.
- Monitoring and automation interface development
- Carry out preliminary and validation tests
- Post-Processing and tests results analysis

6.2 INTERNSHIP ORGANIZATION

This internship had two different phases, not executed in parallel. Figure 17 is a Gantt diagram with a broad outline of the internship planning.

The first weeks were for achieve a global knowledge of the project by reading the MUSCADE deliverables, not only the part that concerns Astrium (therefore this project) but also the rest of the consortium tasks. Also it was the initial contact with the laboratory testbed and the equipment involved in the testbed campaign.

After that, a period of documentation and study of the different encapsulation methods for TV and data transmission by satellite, followed. This first part was over when the state of the art was written and validated.

The second part took up the majority of the internship and it was focused in the monitoring and automation interface and the validation tests. It was divided in several tasks that are specified in section 6.4.

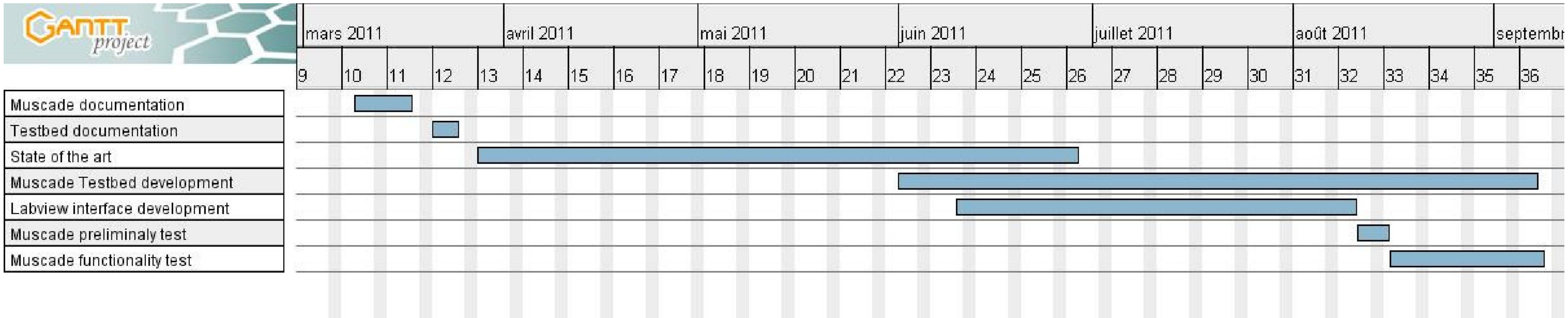


Figure 17: Internship planning

6.3 FIRST PART. STUDY AND STATE OF THE ART

The first part of the end of the study project was to be in charge of writing a satellite TV transmission state of the art document that the ATB3 service will use as a reference for future interns[7].

It was necessary to study several ETSI satellite standards and other complementary information to achieve a deep knowledge of the topic. Alexander Adolf, head of the GSE protocol work group, was very helpful in the writing of the document.

The document named as Appendix I is the state of the art that was written and it is currently in ATB3 network to be consulted for every people of the department.

In order to introduce the TV and data transmission by satellite, a summary of the state of the art in DVB encapsulation is provided in the following paragraph. For further information please refer to Appendix I.

6.3.1 State of the art summary: encapsulation DVB – Satellite

DVB is a set of standards that define digital broadcasting using existing satellite, cable, and terrestrial infrastructure.

DVB-S was developed to provide Direct-To-Home (DTH) services for consumer Integrated Receiver Decoders (IRD), as well as collective antenna systems and cable television head-end stations. DVB-S is suitable for be used on different satellite transponder bandwidths and is compatible with Moving Pictures Experts Group 2 (MPEG 2) coded TV services.

The standard applies only to Ku-band satellites at 11/12 GHz. It is designed to provide Quasi Error Free (QEF) service at BER rates between 10^{-10} and 10^{-11}. By using a fairly robust error protection scheme which can be varied depending on the channel environment, it can provide this QEF rate to channels with non-corrected error rates of 10-1 to 10-2.

The framing structure of the DVB-S is based on the adoption of MPEG-2 multiplex, which allows merging, in a single transport stream, a large number of video, audio and data services.

The conceptual block diagram of the transmission system is shown in figure 18:

- framing structure (based on the MPEG transport multiplex organization)
- signal randomization for spectrum shaping
- advanced error protection (by concatenation of inner and outer codes). 16 bytes of Reed Solomon (RS) coding are added to each 188 byte transport packet to provide Forward Error Correction (FEC) using a RS(204,188,8) code.

[7] Review encapsulation satellite DVB

- flexible coding rate. The basic code rate is ½ but it can be increased up to 5/6, 7/8…
- convolutional interleaving process with depth 12
- baseband pulses are then gray-coded and root raised cosine filtered of α=0.35
- QPSK modulation

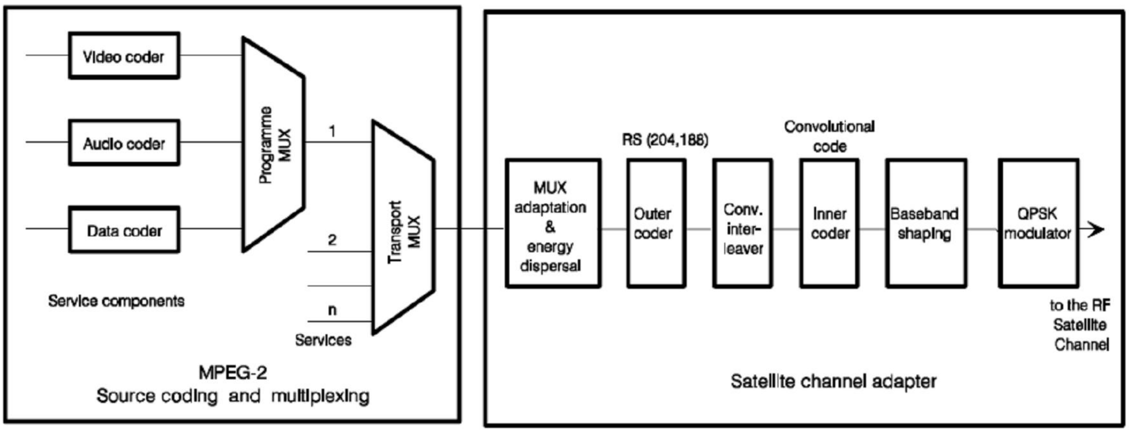


Figure 18 : DVB-S system for satellite digital television

DVB specification provides different broadcast profiles:

- **Data Streaming** - where the data takes the form of a continuous stream which may be Asynchronous (i.e. without timing, as for Internet packet data) Synchronous (i.e. tied to a fixed rate transmission clock, as for emulation of a synchronous communication link) or Synchronised. The data is carried in a Packetized Elementary Stream (PES) formed by an integral number or Elementary Streams (ES). An ES is the output by an MPEG audio, video and (some) data encoders. Transport Streams (TS) are each logically constructed from fragmented PES packets since the PES size is usually longer than the TS packet size (188 bytes).

- **Multi-Protocol Encapsulation** (MPE) - is a Data link layer protocol defined by DVB. It provides means to carry packet oriented protocols (like for instance IP) on top of MPEG TS.

  The MPE encapsulation is performed as follows: the stream is divided in SNDU (Sub Network Data Units) containing a header of 12 bytes and a trailer of 4 bytes (CRC). The SNDU is encapsulated into a series of MPEG-2 transport stream packets belonging to the same logical TS channel.

- **Data Piping (UNIDIRECTIONAL LIGHTWEIGHT ENCAPSULATION)** - where discrete pieces of data are delivered using containers to the destination. ULE has been proposed by the *ipdvb*

Working Group to solve the problems associated with MPE: overhead, complex receiver processing, IPv6 cannot be supported without additional overhead…

As in MPE encapsulation, the datagram is divided in SNDU by adding a 4 byte header and a trailer of 32 bits. ULE is more flexible in terms of higher layer protocols that are supported. ULE header is consequently smaller and carries only mandatory fields:

The **DVB-S2** standard has been specified around three key concepts: best transmission performance, total flexibility and reasonable receiver complexity. To achieve the best performance complexity trade-off – quantifiable in a capacity gain of around 30% over DVB-S, DVB-S2 benefits from more recent developments in channel coding (LDPC codes with BCH) combined with a variety of modulation formats (QPSK, 8PSK, 16APSK and 32ASPK) results in an optimization that closely approaches the Shannon Limit.

DVB-S2 uses information about measured C/N+I ratio (Carrier to Noise and Interference Ratio) on the receiver's side to control and manage transport stream packets on transmitter side, using different modes of coding and modulation. There are three different modes of coding and modulation: CCM (Constant Coding and Modulation), VCM (Variable Coding and Modulation) and ACM (Adaptive Coding and Modulation). Broadcasting applications will utilize CCM and VCM mode while the interactive and professional applications will utilize ACM mode to optimize transmission parameters.

For interactive point-to-point applications, such as IP unicasting, a further increase in the spectrum utilization efficiency of DVBS2 over DVB-S is possible: the Adaptive Coding & Modulation (ACM) functionality allows optimizing the transmission parameters for each individual user on a frame-by-frame basis, dependent on path conditions, under closed-loop control via a return channel.

The System is defined as the functional block of equipment performing the adaptation of the baseband digital signals to the satellite channel characteristics.

The input sequences are:

- single (or multiple) MPEG transport stream multiplexer(s)
- output of a single (or multiple) generic data source(s). This is called single or multiple Generic Streams. Generic Streams can be packetized or continuous: the firsts are particularly suited for carrying fixed-length Protocol Data Units (PDU) such as MPEG2 packets or ATM cells, whereas the latter have been designed to accommodate smoothly any kind of input stream format, including continuous bit-streams and PDUs of variable size such as IP datagrams.

Signal generation is based on two levels of framing structures:

- BBFRAME at base-band (BB) level, carrying a variety of signaling bits, to configure the receiver flexibly according to the application scenario;
- PLFRAME at physical layer (PL) level, carrying few highly protected signaling bits, to provide robust synchronization and signaling at the physical layer.

There are six functional blocks before generating the RF signal:

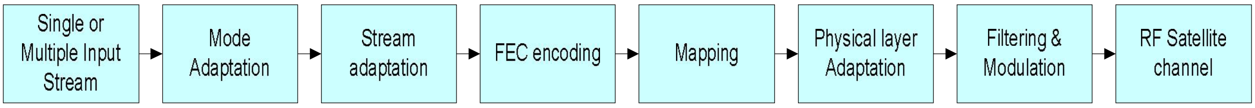


Figure 19 : DVB-S2 System functional block

GSE

The Generic Stream Encapsulation (GSE) is a standard defined for use with the DVB Generic Streams that has been standardized in 2007. The GSE protocol has been devised as an adaptation layer to provide network layer packet encapsulation and fragmentation functions over Generic Stream. GSE provides efficient encapsulation of IP datagrams over variable length Layer 2 packets, which are then directly scheduled on the physical layer into Base Band frames.

With the introduction of the Generic Stream the structure of the stack of protocols for DVB-S2 is as shown in the next figure:

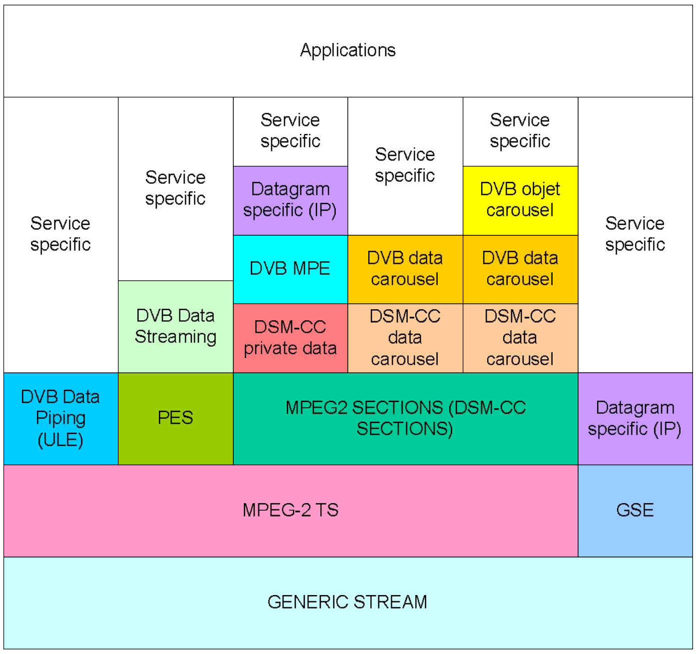


Figure 20 : Protocol stack for DVB-S2

GSE offers lower overhead for IP packets compared to using MPE/MPEG-TS (reducing overhead by a factor 2 to 3). This is achieved without any compromise of the functionalities provided by the protocol, due to the variable length Layer 2 packet size, suited to IP traffic characteristics.

Moreover, it provides flexible PDU fragmentation into arbitrary-sized GSE packets. GSE Packets have in general variable length, in order to match the input IP traffic with minimum overhead. This flexibility was designed to support scheduling for efficient system operation using the Adaptive Coding and

Modulation (ACM) mode of DVB-S2, without mandating any particular ACM forward link scheduling algorithm. GSE also supports non-IPv4 network traffic (IPv6, Ethernet bridging, TS cells, etc) and may be used for unicast, multicast and broadcast. The method is extensible, which could in the future be used to standardise new methods, including DVB-S2 link encryption and IP header compression.

GSE packet format

A Generic Stream consists of a sequence of possibly variable length Base Band frames. GSE Packets are multiplexed and allocated in Base Band Frames.

Each GSE Packet is composed of a GSE Header followed by a GSE Payload, where the (fragment of the) encapsulated PDU is located. The first four fields of the GSE Header are always presents while the rest of them may be omitted depending on the preceding control fields in the first 4 bits of the GSE Header. The minimum GSE header is 2 bytes.

CCM. PDU fragmentation

Each PDU is fragmented if necessary before being encapsulated in GSE packets, to fit GSE packet length to the remaining space in the current Base Band frame datafield and avoid padding. GSE Packets may be sent in different Base Band frames, not necessarily consecutive or with the same transmission parameters (modulation format, coding rate).

A CRC_32 is appended only to the last fragment of a fragmented PDU, GSE relies on the physical layer to ensure the correctness of the transmission. With the CRC_32 only the fragmentation process is checked.

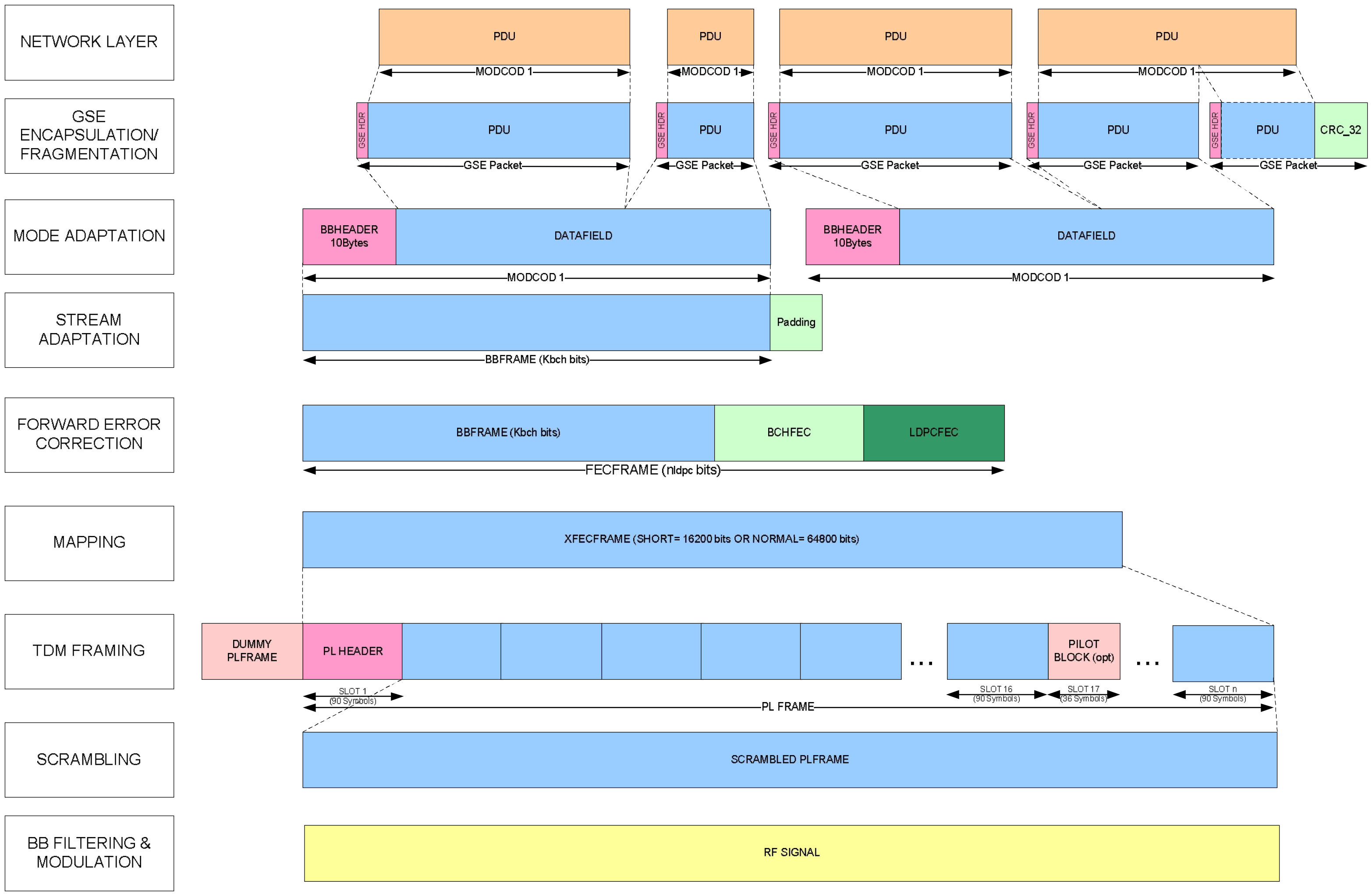


Figure 21: GSE fragmentation with CCM

ACM/VCM. PDU fragmentation

When ACM or VCM are utilized, successive BBFRAMEs can be sent using different ModCods. Since the size and utilization of later BBFRAMEs cannot be predicted, the encapsulated PDU can be fragmented more than once. This is a major difference with DVB-S, in which PDU fragments are sent over the next MPEG2 bearer available, regardless of their sizes or required QoS.

To allocate the different GSE packets in the BBFRAMEs it is necessary to have information of the frame length. When ACM is used, information of the destination channel quality is also taken into account. With a scheduler that performs smart placement of GSE packets into the BBFRAMEs, optimize system efficiency can be achieved. In the situation where no smart schedule strategy is used we could be in the following situation

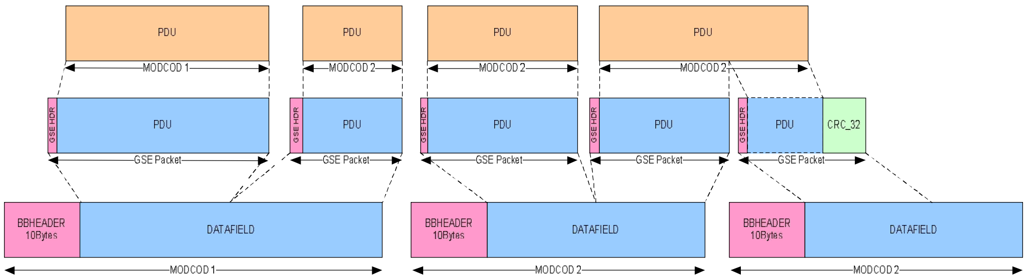


Figure 22: GSE ACM/VCM DISJOINT ENCAPSULATION/SCHEDULING

Due to the disjoint scheduling and encapsulation process the second PDU is encapsulated in a GSE packet and fill in the following BBFRAME available. Since the transmission parameters are constant within a BBFRAME, the GSE packet is allocated in a BBFRAME with a different ModCod.

The overall system efficiency is optimized when a joint operation of scheduling and encapsulation is performed.

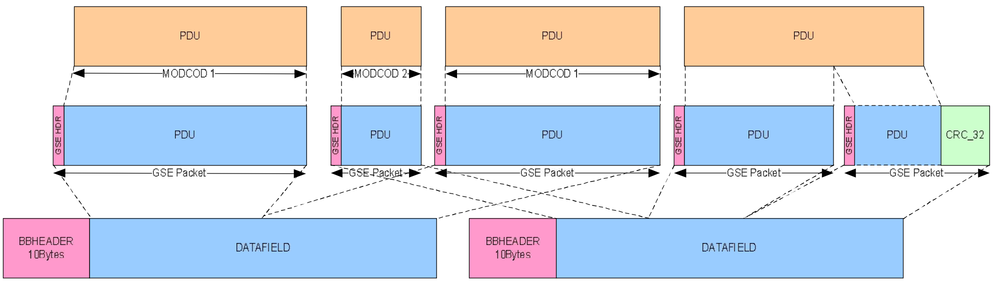


Figure 23: GSE ACM/VCM JOINT ENCAPSULATION/SCHEDULING

This first part of this internship was complemented with the followings additional tasks:

- Participate in the writing of the MUSCADE deliverable “End-to-end network integration & validation plan – Phase I” where the tests we were going to carry out were defined. This document details not only the test for the satellite part but all the other tests to validate every different scenario.
- Antenna installation in the BLUE Lab roof building to point at ASTRA 3B (Ku-band) to be integrated in the validation testbed.
- Work with the satellite constructor (NEWTEC) to carry out the update of the equipments in order to perform GSE encapsulation.

6.4 SECOND PART. MUSCADE SATELLITE TESTBED CAMPAIGN

The objective of the second part of the internship was to participate in the satellite testbed campaing. It was necessary to develop a graphic interface for monitoring and automation programmed in Labview language.

This graphical interface helped to provide the functional verification of the end-to-end transmission and to carry out the tests engaged in the deliverable “End-to-end network integration & validation plan – Phase I”. This Graphical User Interface (GUI) was used to validate the end to end satellite chain and to test the performance of the solution proposed by the consortium MUSCADE in different scenarios (fading profiles, rates combinations, static and moving images, reception antenna sizes…)

Finally, the post process of the test results was necessary to state the correct behaviour of the whole end-to-end network.

6.4.1 End-to-end network

Figure 24 shows the reference architecture of the end-to-end satellite chain. As it can be observed is divided in two phases.

The first one corresponds to the emulated channel, where the real satellite link is replaced by a Channel Simulator, a device that has the capability of simulating satellite links and that subjects the signals to various impairments, as fading or interferences, and also adds the typical satellite delay of 250ms.

Geostationary satellites, mostly used in communication, are placed at an altitude of approximately 35785 Km above the equator. Knowing that the radio waves go at the speed of light, which is 300,000 km per second, and that the up and down distance they travel is 72000 Km the calculated delay has a value of 250 ms.

After the validation of this phase the 3D media chain will be tested under real link conditions passing though the satellite network. The environment to perform these simulations was provided by SES ASTRA that supplied access to one of the satellites they operate.

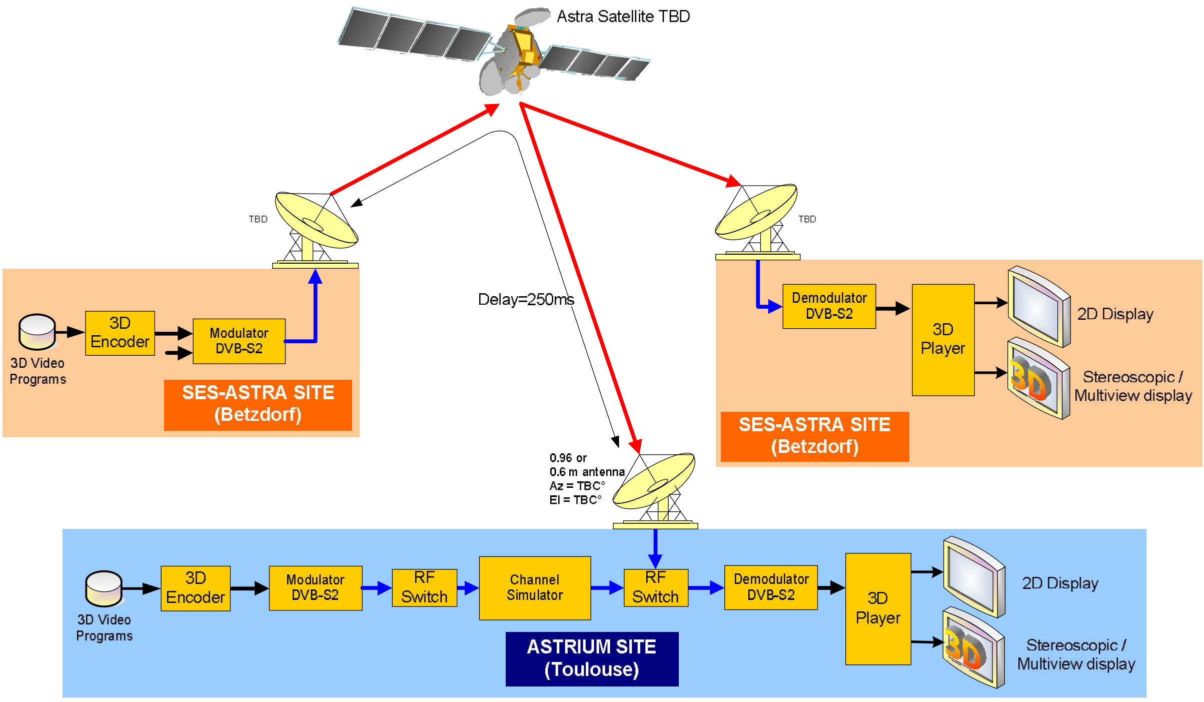


Figure 24: MUSCADE end-to-end architecture

As it can be seen in figure 24 the 3D content, encoded in the format proposed by MUSCADE, is modulated by a DVB S2 modulator and demodulated and finally rendered in different 3D players. The agnostic video render allows the video to be played either in a 2D display (traditional TV) or in a stereoscopic or multiview (without glasses) display[8].

The uplink was performed from Betzdorf, SES ASTRA site while Astrium only performed the downlink.

This end of study project was placed in Phase I and, therefore, involved only the emulated environment.

[8] Autostereoscopic display

6.4.2 List of Equipments

In this section a description of the devices used in the testbed is provided. Equipments belonging to the satellite emulated chain are placed in the rack shown in figure 25.

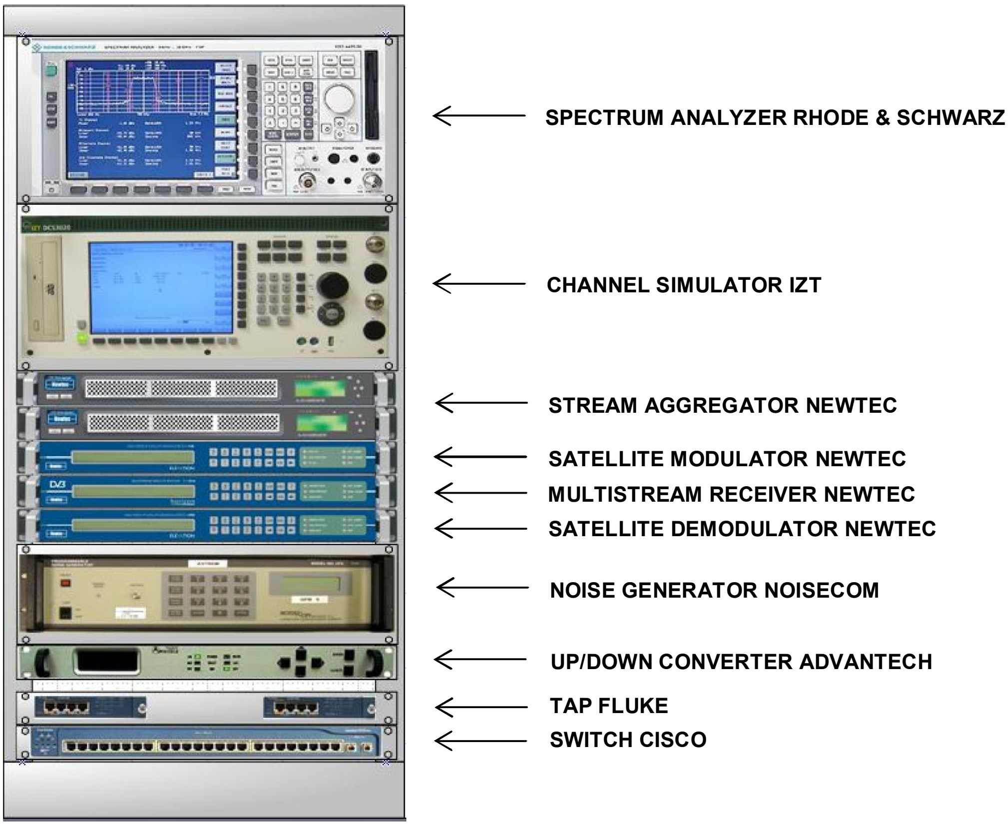


Figure 25: MUSCADE Rack

- **Streaming Video Server**:

This equipment is a PC with an ASI Card (DekTec DTA-2160) which streams the different Transport Stream containing the multi-layered 3D media (stereoscopic, ΔMVD2 and ΔMVD4). The streaming video server provides two types of outputs: ASI and IP.

- **Stream Aggregator**:

This device is a Newtec AZ810 which allows aggregating several ASI transport streams inputs in one satellite carrier (BBFrames over Ethernet). It is designed to be used together with the broadcast modulator and it supports VCM mode.

- **DVB-S2 Modulator:**

The modulator is a Newtec EL178, a satellite modulator optimized for ASI & IP applications over satellite (two different interfaces). This equipment is compliant with the DVB-S2 standards and supports CCM, ACM and VCM mode. The modulator supports ULE, MPE, GSE and XPE (Newtec propriety).

- **Channel Simulator:**

The modulated signal leaves the modulator and goes through a wideband, digital Channel Simulator: the IZT DCS 3020. This device is especially designed for simulating satellite links. Its signal processing also allows for applying noise with different fading channel models, delay etc.

- **DVB-S2 Receivers:**

Two different demodulators are used on the test Bed.

- o The first Demodulator is a HZ914 from Newtec. It is a multistream satellite receiver and it is in charge of receiving and decoding the RF signal. It provides several ASI outputs through which the different Transport Streams are sent to the streaming video receiver. The other option is to use a stream aggregator to receive the three different TS and to convert them in TS over IP.
- o The second is an EL978 from Newtec. This demodulator is used in IP mode (GSE encapsulation)

- **Noise Generator**:

This equipment is a noise generator that can generate different fading models via input files to emulate the satellite link degradations. Different fading patterns of real satellite link are been recorded to feed the noise generator in the test phase. A noise generator was used instead of introduce the distortion signal by the channel simulator because it is going to be used also in the real link tests.

- **Streaming Video Receiver**:

This equipment is a PC which receives the multi-layered 3D contents over the ASI or IP connections through a Dektec card (DekTec DTA-2160). It can record the different Transport Streams that have been affected by the fading generated in the Channel Simulator. VideoLan (VLC) is also used to play or record the different video layer when the chain is used in IP mode

- **<u>Spectrum Analyzer</u>**

This device is a FSP Rhode Schwarz spectrum analyzer and it is used to monitoring the signal at the demodulator input.

- **<u>TAP</u>**

This device copies and reproduces each IP packet transmitted, and sends the copy to a traffic analyser software (RIO) in order to monitor the traffic without adding any interference to the test.

At the end of the chain the followings displays will be used:

- **<u>Conventional TV</u>:** SONY BRAVIA KDL-46W4000 46”
- **<u>Stereoscopic 3D TV</u>:** HYUNDAI S465D 46”
- **<u>Auto-stereoscopic 3D TV:</u>** ALIOSCOPY 3DHD 42’’

6.4.3 List of software

- **<u>Labview</u>**

  Labview is a platform and development environment for a visual programming language from National Instruments. The purpose of such programming is automating the usage of processing and measuring equipment in any laboratory setup. It is commonly used for data acquisition, instrument control and automation.

- **<u>RIO Tool</u>**

  RIO is a link-oriented IP sniffer developed by Astrium. This tool captures the IP packets entering the PC it is installed on, and give some statistics on the IP traffic. Instead of capturing the packets on 1 point as Wireshark and simply give information on the packets and the bitrate, RIO gets the packets from 2 points, dynamically compares them and then provides various statistics, like the loss that have occurred, the delay of transmission, and the jitter. It can also provide more casual statistics, such as the bitrate. It is particular useful in the field of satellite when knowing the characteristics of the whole link is more interesting that getting a local information which is not really relevant.

  Another feature of RIO is the filtering of the traffic according to several IP packet fields:

  - Protocol
  - Source IP

- Destination IP

Finally, when a capture is over, RIO can export the results and save the graphs.

In order to be able to sniff the traffic without disturbing it, it is necessary to duplicate the traffic and send the copy to the RIO tool while the original goes its way. This way RIO can analyse the traffic without being intrusive. We will use network TAP that reproduces each packet at level 1 and redirects them to another output.

- **TV Software**

    - DtTV: is a MPEG2 Transport-Stream Television software of Dektec.
    - StreamXpress: Playout software for Dektec output adapters
    - VLC: is a free and open source multimedia player, encoder and streamer.

6.4.4 Testbed architecture

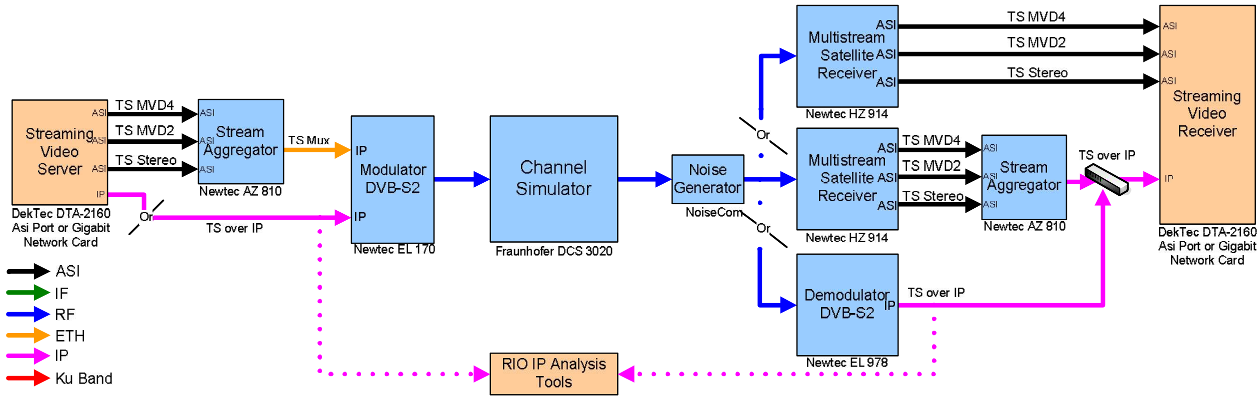


Figure 26: MUSCADE Satellite Testbed Architecture

The proposal satellite testbed architecture for MUSCADE is described in figure 26. This testbed architecture aims to be compliant with all the possible scenarios. In order to assure this, three different configurations, with different equipments, have been defined and tested.

6.4.5 Testbed configurations

In every configuration, two PCs represented the video server and the video receiver, both using a DekTec card.

6.4.5.1 Configuration 1

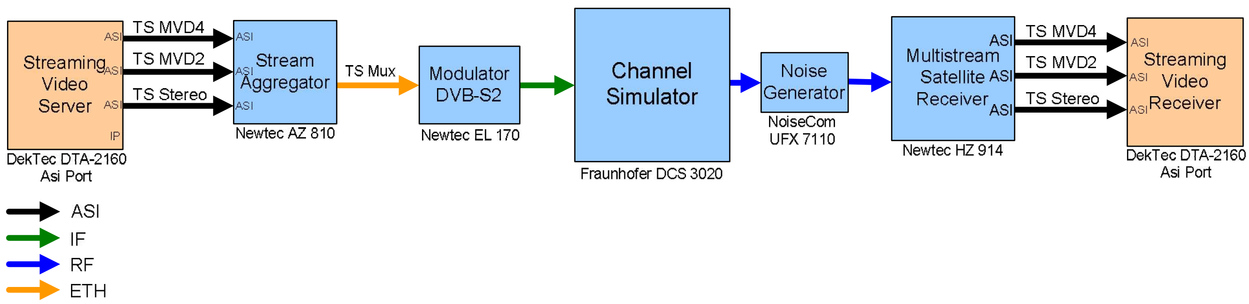


Figure 27: MUSCADE Satellite Testbed - Configuration 1

In this configuration, the input to the satellite emulated chain is in TS format, i.e. it is transported by and ASI signal. ASI is a high-bandwidth (216 megabits per second) widely used electrical interface designed to be used as input to and output from broadcast, cable and satellite encoders and similar transmission equipment which often carries an MPEG Transport Stream.

A Stream Aggregator is placed before the modulator to multiplex the three different ASI inputs into a TS multiplexed by an Ethernet output.

The modulated signal goes past the channel simulator and the noise generator. The channel simulator is capable for itself of simulating a fading event but an external device to introduce a noise signal was used instead.

The reason of that is because in phase II, real link, the channel simulator is replaced by a real satellite link. This device was placed in order to recreate a fading event in reception if the weather conditions didn't provide it.

In the render extreme we used a demodulator that split the RF signal into the three TS streams (Stereo, ∆MVD2, ∆MVD4). In this format (ASI) they are sent to the PC that used suitable render software to play the videos.

This configuration is called TS native because both sides are streamed by ASI ports.

In this case we used StreamXpress to stream the videos and DtTV to play them.

6.4.5.2 Configuration 2

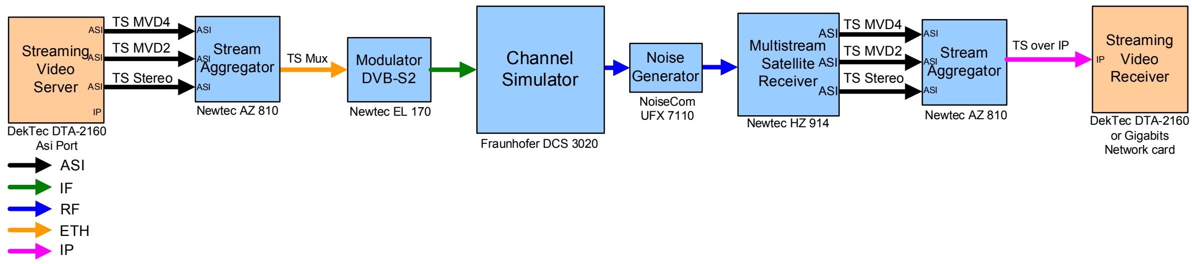


Figure 28: MUSCADE Satellite Testbed - Configuration 2

In this configuration the emission side is exactly the same as in configuration 1. The only difference is that the videos are rendered by an Ethernet input. So, a stream aggregator was placed after the multistream receiver to multiplex the signal into an Ethernet output (TS over IP) that is connected to the receiver server.

StreamXpress or DtTV was used again to stream the three videos but, in this case, VLC was the choice in reception to play them.

6.4.5.3 Configuration 3

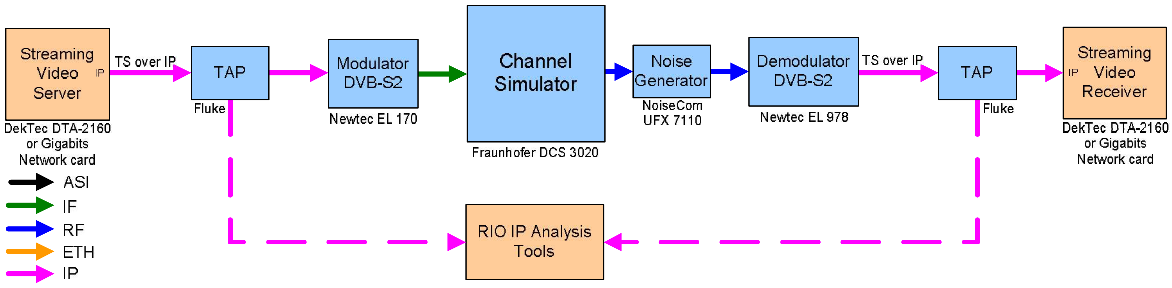


Figure 29: MUSCADE Satellite Testbed - Configuration 3

The aim of this configuration was to simulate an all IP scenario. In this configuration GSE encapsulation was used to send the TS packets in the BBFrames. The modulator is the same but the multistream receiver was replace by an IP demodulator (EL 978) that better supports the video bitrate used in MUSCADE test and that is specially designed to perform end to end IP transmission.

The device called TAP, placed between the streaming video server and the modulator and between the demodulator and the video receiver, was used to make a copy of the IP flow that is analysed by an IP sniffer (RIO sniffer).

In this case VLC, as streaming/rendering software, was used in both sides.

6.4.6 Monitoring and automation in Labview

This section describes the Labview tool implemented to carry out the test needed to validate the correct running of the satellite testbed.

- Analysis: where the requirements of the monitoring tool are expressed.
- Design: a block diagram with the main functions to be implemented
- Implementation of specifications defined in the analyses using Labview language.

6.4.6.1 Analysis

The MUSCADE graphic interface objective was to be a tool that allows the tests automation and the data acquisition from the testbed devices.

The following parameters and metrics had to be extracted from the equipments for evaluate the performance of the transmission tests:

- <u>**Es/No**</u>:

Symbol energy to noise ratio. It is measured at the input to the receiver and is used as the basic measure of how strong the signal is. This metric is ModCod dependant.

$$\frac{E_S}{N_0} = \frac{E_b}{N_0} \cdot \log(M)$$

Where E_b = energy per bit (J)

N_0 = noise spectral density (Watts/Hz)

M = number of modulation symbols

- **Threshold:**

Point after the signal level is about to cross the Quasi Error Free operation. That means that from this point, the streamed video will not be able to be demodulated correctly.

- **Link margin:**

Indicates the receive margin before reaching the threshold point of QEF (Quasi Error Free) operation. The performance of the DVB-S2 system is defined at the quasi error-free (QEF) point. This is the level at which the system is nearly but not quite failing - where decoded picture or sound errors are so infrequent as to prove unnoticeable. The QEF point for DVB-S2 is approximately corresponding to a Transport Stream Packet Error Ratio PER< 10-7 before the de-multiplexer.

- **Bitrate**:

Number of bits processed per unit of time.

- **Lost Packets**

Amount of packets that travelling though the network never reaches its destination.

- **Delay**

The packet transfer delay is mesured between the points where the TAP is place, i.e. there will be only information about the delay in configuration 3 (all in IP). As it was explained before, the typical satellite delay for satellite in geostationary orbit is 250 ms.

- **Jitter:**

Is a variation in packet transit delay caused by queuing, contention and serialization effects on the path through the network.

During the test campaign, three different configurations have to be tested (see 6.4.4 section).

- **Configuration 1**: TS native end to end
- **Configuration 2**: TS native on Gateway Side (emission side) and TS over IP on terminal Side

- **Configuration 3**: IP end to end using GSE encapsulation.

The MUSCADE GUI will have to perfom tests by changing these parameters:

- Different ModCod per stream (VCM) or same ModCod for all streams (CCM)
- Different fading profiles
    - Constant fading
    - Up and down ramp generated by the noise generator
    - Emulated fading.

    These fading profiles are extracted from an analyser spectrum connected to an antenna placed in the BLUELab building roof. This antenna is pointed to the Astra 3B (Ku Band, 23.5° E). Another monitoring tool developed in Labview is in charge of creating files with the signal level in case that a true fading event happened (rain storm per example). We have around 20 different fading profiles created by this method. See Appendix V for further information of the emulated fading profiles[9].
- Possibility to switch between layers (Stereo, ∆MVD2 and ∆MVD4), send only the Stereo&∆MVD2 videos for example.

Finally, the monitoring tool had to export to a file the metrics recovered during the tests and also render the same parameters in real time graphs.

6.4.6.2 Design

The language used to implement this tool is LabVIEW. LabVIEW graphical programs are called Virtual Instruments (VIs). VIs run based on the concept of data flow programming.

A VI consists of two components: a Front Panel (FP), and a Block Diagram (BD). A FP provides the user-interface of a program while a BD incorporates its graphical code.

Figure 30 shows the main schema of the BD programmed interface.

[9] Fading profile examples. Appendix VI

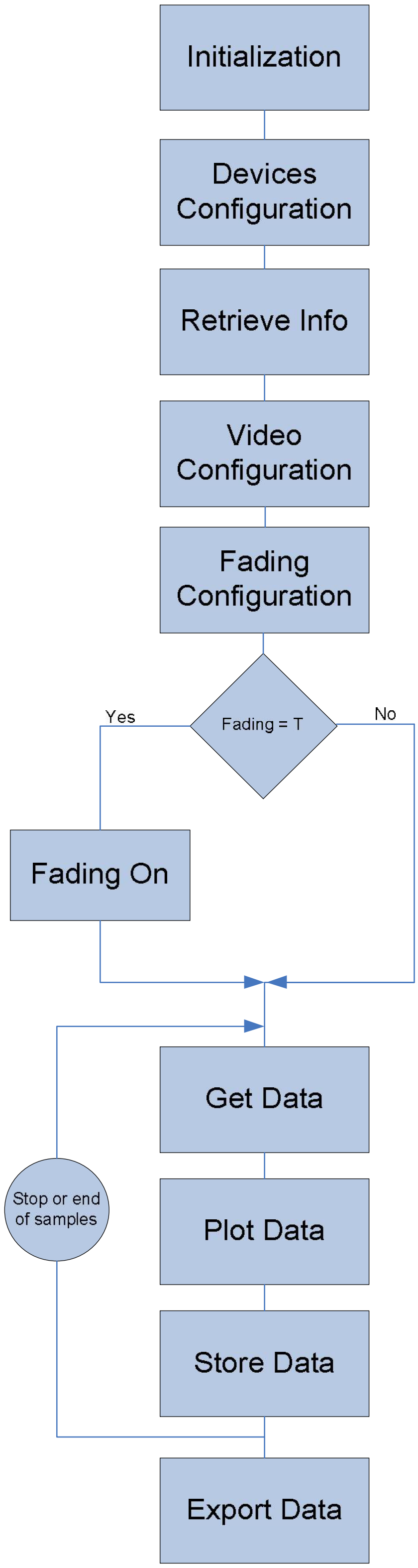


Figure 30: MUSCADE monitoring tool block diagram

6.4.6.3 Communication Labview-equipments

To collect tests data and set the test conditions (i.e. noise level in the channel simulator) the developed interface had to be capable to set a communication with the different devices that form the satellite media chain.

In order to achieved that, the following protocols were used:

- **SNMP**

  The Simple Network Management Protocol (SNMP) is a TCP/IP protocol for network management. Network administrators use SNMP to monitor and map network availability, performance, and retrieve information from an SNMP-capable device by command-line applications.

  To work with SNMP, network devices utilize a distributed data store called the Management Information Base (MIB). All SNMP compliant devices contain a MIB which supplies the pertinent attributes of a device.

  SNMP commands are used to read and write data in each device MIB. 'Get' commands typically retrieve data values, while 'Set' commands typically initiate some action on the device.

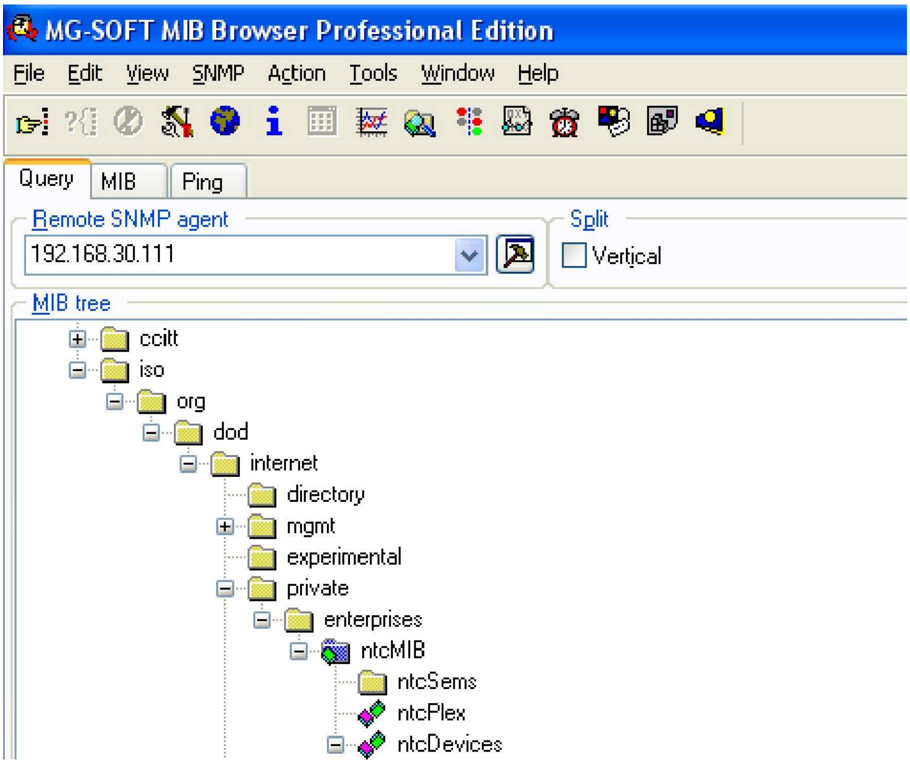


Figure 31: MIB Browser example

This system was used to communicate from the Labview interface with the NEWTEC devices (modulator, demodulator, multi stream receiver and stream aggregator).

- **GPIB**

  General Purpose Interface Bus was specifically designed to connect computers, peripherals and laboratory instruments so that data and control information could pass between them. It is also known as IEEE-488 or HPIB.

  This protocol was be used to communicate with the Noise Generator and set the noise level for the fading profiles and with the Spectrum Analyzer to configure it.

- **TELNET**

  Telnet is a network protocol used on the Internet or local area networks to provide a bidirectional interactive text-oriented communications facility using a virtual terminal connection. User data is interspersed in-band with Telnet control information in an 8bit data connection over the TCP.

  The Channel Simulator used this protocol.

6.4.6.4 Management and traffic network

Two different networks have been created for the testbed: the first one was used for the management and included the satellite devices (modulator, demodulators and stream aggregator), the router, the RIO Station and the GPIB/Ethernet converter.

The management addressing plan and the protocols used to communicate with each equipment involved in the testbed platform are shown in figure 32.

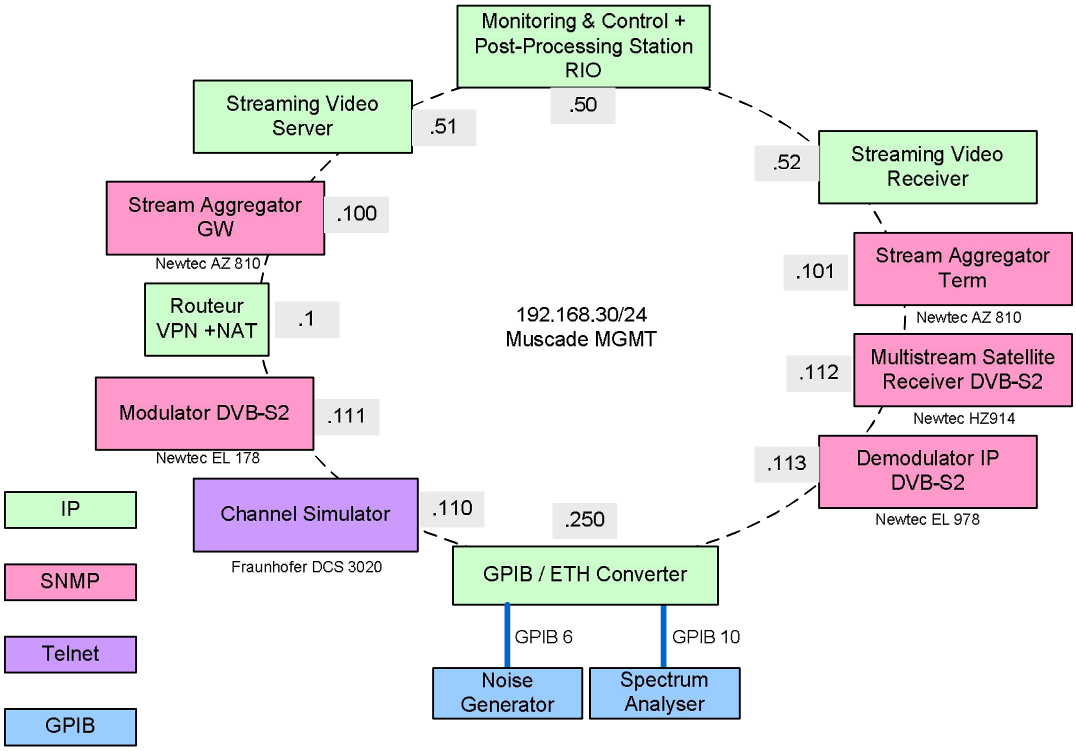


Figure 32: Management addressing

The second network, figure 33, was used exclusively to stream the videos. Therefore, only the two pc that execute the tasks of streaming and rendering and the satellite equipment were included.

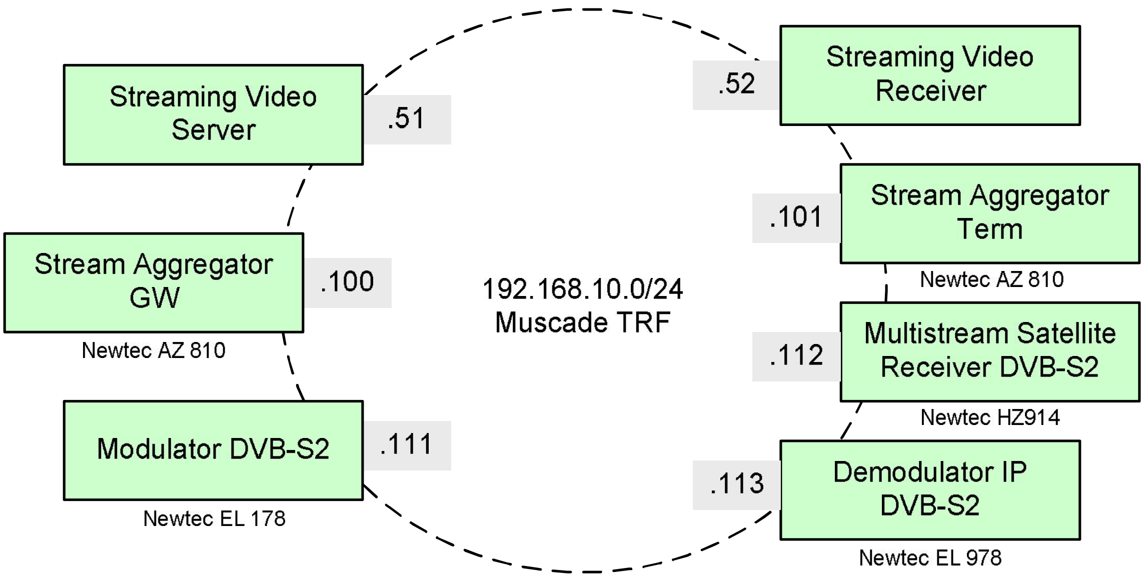


Figure 33: Traffic addressing

6.4.6.5 Implementation

In this section specific details of the implementation are described.

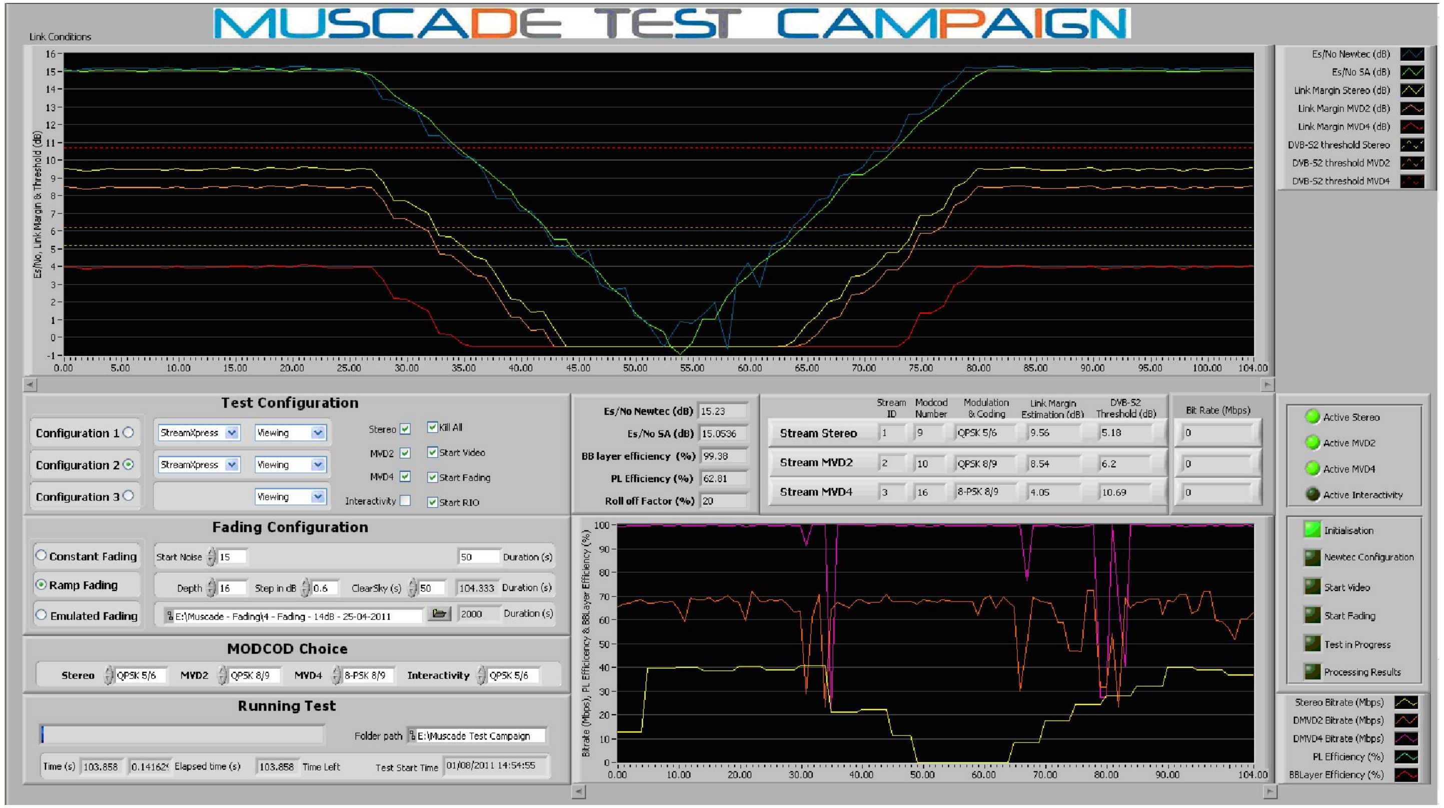


Figure 34: MUSCADE Test Campaign GUI- Front Panel

The front panel of the monitoring interface of MUSCADE was divided in three principal blocks.

- Test Configuration
- Acquired parameters and graphics
- Running Test

<u>Test Configuration</u>

The first block concerns to the test configurations. As there are 3 different configurations we could choose one of them and, depending of our choice, have different steaming options (several softwares). For the configuration 3 (all in IP) only VLC was used so there was no combo box. Also it was possible to choose between play or record the video.

To carry out the different tests, every stream: Stereo, MVD2 and MVD4, can be launched separately.

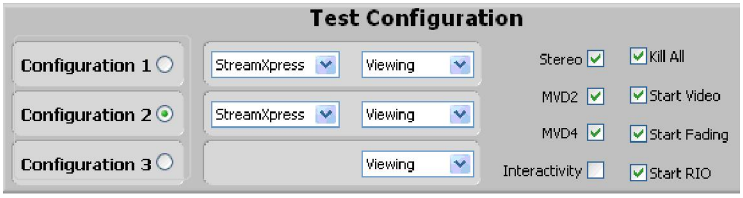


Figure 35: Test Configuration

Different ModCods were applied to each stream in order to provide different error protection per TS. There was possible to choose between the 28 possible different ModCod.

Figure 36: ModCod Choice

Fading configuration can be chosen in the FP part show in figure 37. The three types were implemented.

- **Constant Fading**: create a constant noise level fixed by the parameter *Start Noise* during a certain amount of time that limits the test duration
- **Ramp Fading**: by fixing the *Depth*, the *ClearSky* (amount of time that the signal remains unaffected by the fading) and the *Step in dB* (how many dB falls the signal in a time unit) a ramp signal is created in the noise generator and will be applied to the transmitted signal.

  In this case, the duration was calculated depending of these three parameters.

- **Emulated Fading:** From a browser we could choose between different 'real fading' profiles which are named with their deepest dB loss. The duration was also calculated depending on the sample numbers in the text file created.

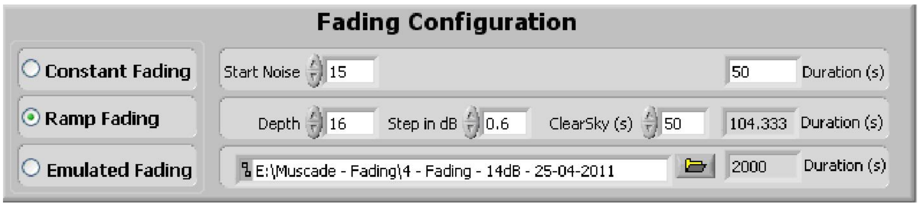


Figure 37: Fading Configuration

__Acquired parameters and graphics__

The following metrics are recovered from the different equipments:

- E_s/N_0 from Newtec devices in dB
- E_s/N_0 from Spectrum Analyser in dB: we use a second device to get the same metric because when is a fading event, the demodulator is not able to measure the signal level, while a Spectrum Analyser has a better sensibility and is able to provide this information.
- BB Layer Efficiency: This value displays the baseband layer efficiency of the DVB-S2 modulator. The BBL efficiency is expressed in % and is calculated as the ratio between used payload bytes and available payload bytes within the Baseband frames. It is the filling level of the DVB-S2 baseband frames.
- PL Efficiency: This value displays the physical layer efficiency of the DVB-S2 modulator. The PL efficiency is expressed in % and is calculated as the ratio between dummy PL-frame symbol-rate and available symbol rate. It is 100 % when no dummy PL frames are inserted.
- Link Margin in dB of every level of scalability
- Threshold in dB of every level of scalability
- Bitrate in Mbps of every level of scalability. This can only be acquired for the configuration 1 & 2. With the GSE encapsulation the demodulator is not able to split the streams and only gives the global bitrate. In this case we will use the RIO software to get this information.

The info retrieve interval is programmable but for our test is set to 1 s.

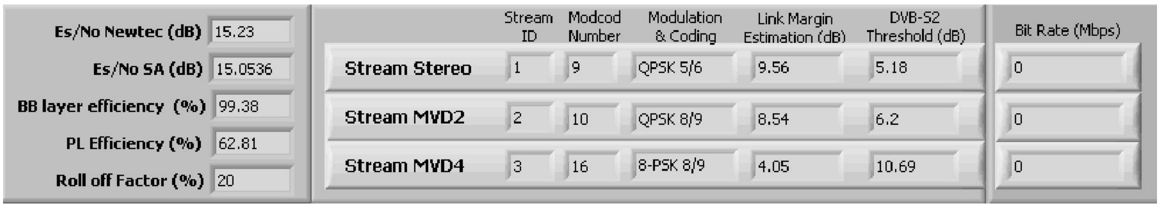


Figure 38: Data recovered

With all this data, two graphics were displayed in real time: the first one, figure 39, shows the Link Conditions representing the E_s/N_0, Link Margin and Threshold. The horizontal axis is automatically established to the test duration.

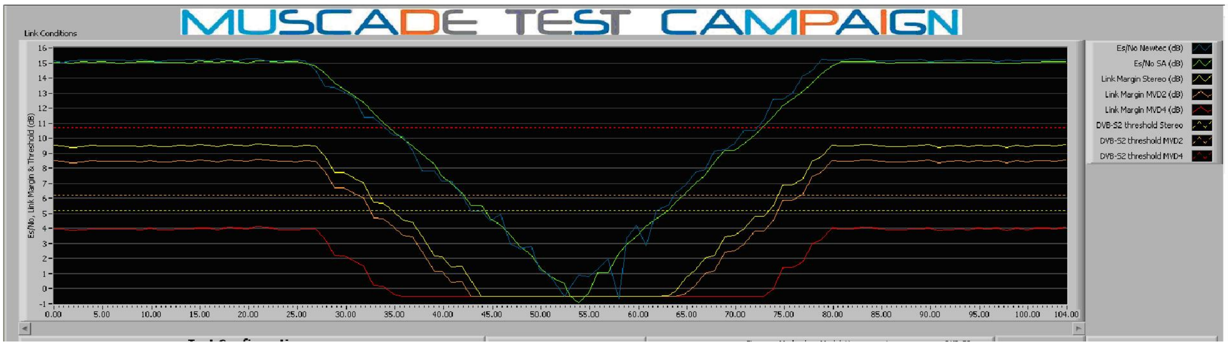


Figure 39: Link conditions Graph

The second graph was used to display the efficiency information and the bitrate. In the case of configuration 1&2 we had a graph that shows the three scalability levels bitrate as in the figure 40.

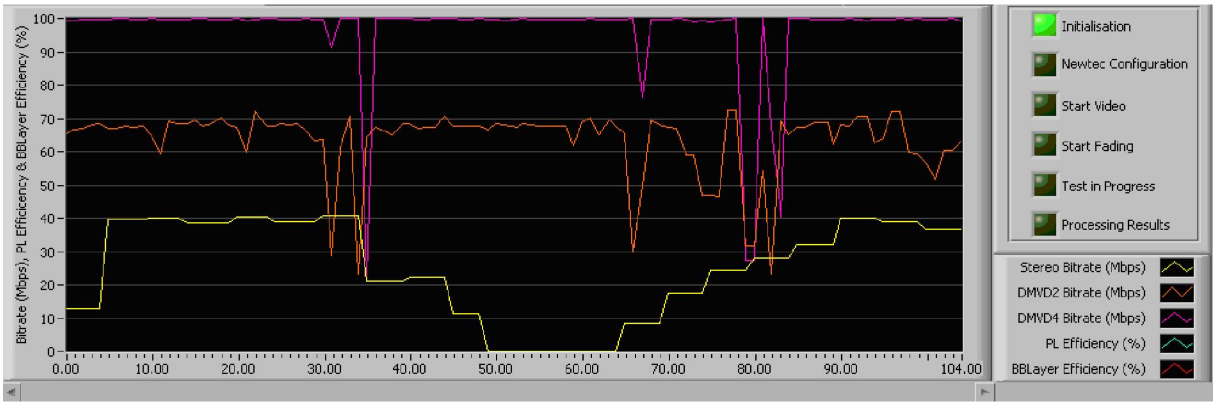


Figure 40: Link Conditions 2 Graph in Configuration 1&2

While in configuration 3 we had only the global bitrate.

Running Test

Several visual indicator were programmed to provided running test information, elapsed time, time left, test start time …

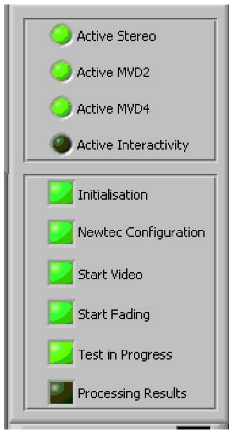


Figure 41: Running Test

Automation

One of the objectives of the graphical interface was to automate the test campaign. To achieve this, several actions were managed from this program.

- **ModCod choice**

  Labview set the suitable parameters in each configuration to be able to receive the chosen ModCods.

- **Video Configuration**

  The program communicates with the PCs streamer and receiver to launch the fitting software. It executes a certain .bat file that contains the command line necessary to send and receive each stream. In reception the three streams are played at the same time in the screen.

- **Data export**

  To export the acquired data though each tests a excel file filled in with the results needed in the post processing process was created by Labview.

- **Rio Tool**

  The launch of the IP sniffer, RIO, was also automatic. As for the videos, the interface executed a file that launched RIO and exported their results in a excel file.

6.4.7 MUSCADE ModCod choice for satellite network

MUSCADE scenario for satellite network is Ku-band over Europe. Ku band is primarily used for satellite communications, particularly for editing and broadcasting satellite television. In Europe, Ku band is used from 10.7 to 12.75 GHz for direct broadcast satellite services such as those carried by the Astra satellites. For broadcasting satellite services the frequencies used are 12.2-12-75 GHz.

When frequencies higher than 10 GHz are transmitted and received in a heavy rain fall area, a noticeable degradation occurs (rain fade). This problem can be combated, however, by deploying an appropriate link budget strategy when designing the satellite network.

As an example, the ASTRA 1E satellite located at 23.5° east was considered. This satellite is used by SES-ASTRA to run 3D demonstration channels at the time of writing this report (September 2011). Figure 42 shows the saturated EIRP performances over the satellite coverage area, in the BSS (Broadcasting Satellite Service) frequency band (11.70 -12.10 GHz) and with vertical polarization.

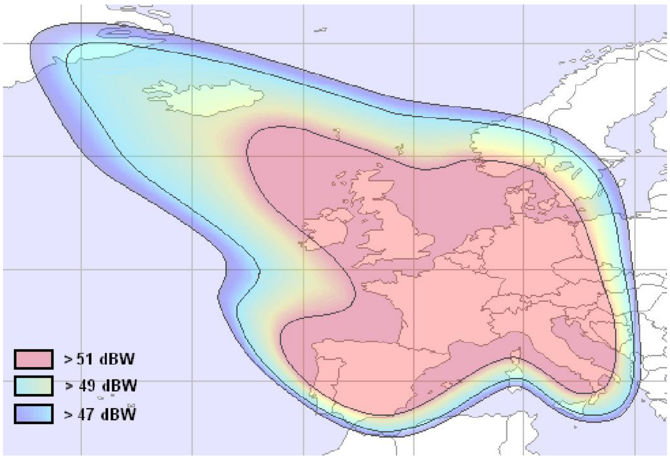


Figure 42: Astra 1E EIRP performances (BSS, V-pol)

In the BSS frequency band, the transponders bandwidth is 33 MHz, each one being fed with a single 27.5 Msps carrier. This scheme allows operating the power amplifier near the saturation, optimising the use of the on-board power resources without generating intermodulations.

The most common type of terminal antenna is the parabolic reflector, a.k.a. the satellite dish. The parabolic shape of the dish reflects the signal to the dish's focal point where the feed horn is placed. The size of the antenna may vary. Typical antenna sizes for home reception in Ku-band range from 60cm to 100cm.Usually small antennas are used at the centre of the coverage where satellite EIRP is high whereas larger antennas are used at the edge of the coverage. However, a large antenna can be used at the centre of the coverage in order to benefit from high link availability, i.e. a better service.

Figure 43 illustrates the recommended dish sizes for proper Astra 1E programs reception (BSS, V-pol) depending on the location.

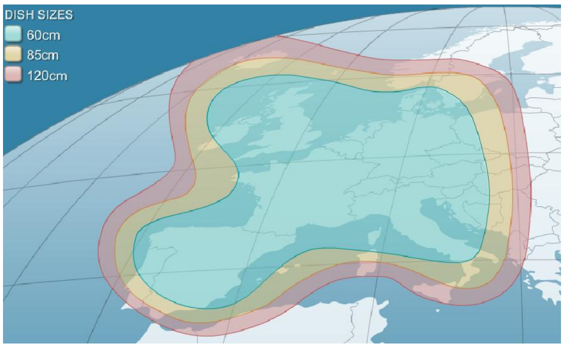


Figure 43: Recommended dish sizes for reception of Astra 1E services (BSS, V-pol)

According to SES ASTRA for Ku band, a typical bandwidth budget for satellite networks is:

- 42 Mbps with a 60cm antenna in QPSK4/5 transmission mode.
- 53 Mbps with a 80cm antenna in 8-PSK2/3 transmission mode

In the table of figure 44 the 28 available ModCods in DVB S2 protocol with his spectral efficiency can be found. This table was created with the spectral occupancy per ModCod provided by Newtec (satellite equipments constructor).

	Codage Rate	MODCOD	Spectral efficiency (bit/symbol)	Measured Es/No Treshold	Theoretical Es/No	Delta between theory and measurement
QPSK	QPSK 1/4	1	0.479	-2.2 dB	-2.4 dB	0.2 dB
	QPSK 1/3	2	0.641	-1.0 dB	-1.2 dB	0.3 dB
	QPSK 2/5	3	0.771	0.2 dB	-0.3 dB	0.5 dB
	QPSK 1/2	4	0.965	1.4 dB	1.0 dB	0.4 dB
	QPSK 3/5	5	1.160	2.7 dB	2.2 dB	0.5 dB
	QPSK 2/3	6	1.291	3.4 dB	3.1 dB	0.3 dB
	QPSK 3/4	7	1.452	4.4 dB	4.0 dB	0.4 dB
	QPSK 4/5	8	1.549	5.1 dB	4.7 dB	0.4 dB
	QPSK 5/6	9	1.615	5.4 dB	5.2 dB	0.2 dB
	QPSK 8/9	10	1.724	6.5 dB	6.2 dB	0.3 dB
	QPSK 9/10	11	1.746	6.8 dB	6.4 dB	0.4 dB
8-PSK	8-PSK 3/5	12	1.740	6.1 dB	5.5 dB	0.6 dB
	8-PSK 2/3	13	1.936	7.1 dB	6.6 dB	0.5 dB
	8-PSK 3/4	14	2.178	8.3 dB	7.9 dB	0.4 dB
	8-PSK 5/6	15	2.422	10.0 dB	9.4 dB	0.7 dB
	8-PSK 8/9	16	2.586	11.2 dB	10.7 dB	0.5 dB
	8-PSK 9/10	17	2.618	11.7 dB	11.0 dB	0.7 dB
16APSK	16-APSK 2/3	18	2.575	9.5 dB	9.0 dB	0.5 dB
	16-APSK 3/4	19	2.896	10.8 dB	10.2 dB	0.6 dB
	16-APSK 4/5	20	3.090	11.8 dB	11.0 dB	0.8 dB
	16-APSK 5/6	21	3.222	12.4 dB	11.6 dB	0.8 dB
	16-APSK 8/9	22	3.440	13.8 dB	12.9 dB	0.9 dB
	16-APSK 9/10	23	3.483	14.0 dB	13.1 dB	0.9 dB
32APSK	32-APSK 3/4	24	3.623	13.8 dB	12.7 dB	1.1 dB
	32-APSK 4/5	25	3.866	14.8 dB	13.6 dB	1.2 dB
	32-APSK 5/6	26	4.031	15.4 dB	14.3 dB	1.1 dB
	32-APSK 8/9	27	4.303	16.9 dB	15.7 dB	1.2 dB
	32-APSK 9/10	28	4.357	17.2 dB	16.1 dB	1.2 dB

Figure 44: DVB S2 ModCod LIST

We applied different ModCods on every one of the scalability levels. Stereo layer, that contains the stereoscopic view + audio + interactivity, had to be the best protected, so it was coded with a robust ModCod. MVD2 and MVD4 were coded with higher ModCods, they are more sensitive to fading but they have a smaller spectral occupancy. Therefore, with this kind of choice the needed bandwidth for the transmission was reduced.

The followings ModCods, represented in figure 45, were chosen for being the typical transmission parameters with the recommendation of ASTRA.

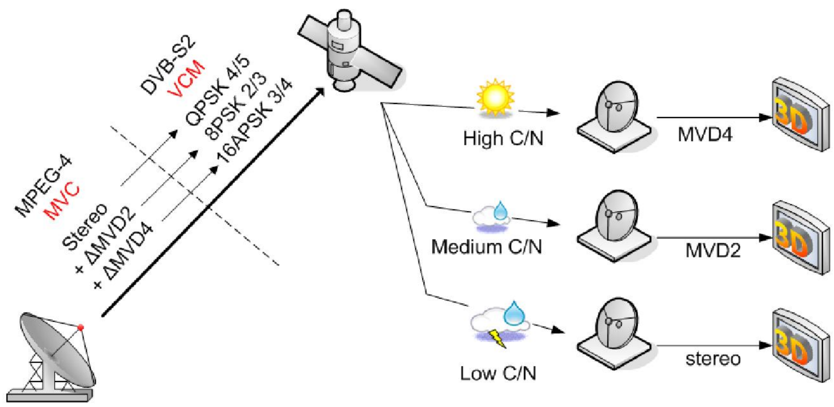


Figure 45 : ModCods provided for MUSCADE test

Calculating the spectral occupancy for the 3 ModCod It was verified that the signal didn't go the limit of 33MHz.

Modulation Type	Layer	Bitrate (Mbits)	Modulation	Threshold	Spectral Efficiency	Baudrate	Spectral occupancy
VCM	Stereo	13	QPSK 4/5	5,1	1,5494 bit/sym.	8,3902 Mbaud	10,0682 MHz
	ΔMVD2	7	8-PSK 2/3	7,1	1,9357 bit/sym.	3,6163 Mbaud	4,3396 MHz
	ΔMVD4	17	16-APSK 3/4	10,5	2,8963 bit/sym.	5,8695 Mbaud	7,0434 MHz
	Interactivity	0	QPSK 4/5	5,1	1,5494 bit/sym.	0,0000 Mbaud	0,0000 MHz
	Total	37			Total	**17,876**	**21,451**

Figure 46: Spectral occupancy in VCM mode

Being

$$Baudrate = \frac{Bitrate(Mbits)}{SpectralEfficiency(bits/symbol)}$$

$$Spectral\_Occupancy = Baudrate \cdot (1+\alpha)$$

with $\alpha \equiv Rolloff\_factor = 20\%$

To confirm the advantage of using VCM we did the same calculations for a transmission in CCM with QPSK 4/5 (stereo layer). As it can be seen in figure 47 we send the same information using more of 7MHz that with VCM.

Modulation Type	Layer	Bitrate (Mbits)	Modulation	Threshold	Spectral Efficiency	Baudrate	Spectral occupancy
CCM	ALL	37	QPSK 4/5	5,1	1,5494 bit/sym.	**23,880**	**28,656**

Figure 47: Spectral occupancy in CCM mode

These tables are made under the following conditions:

- Pilot symbol insertion activated. This helps the synchronization in reception.
- FEC FRAME size normal = 64800 bits. This is the normal size in TV broadcasting, short frame is used normally when the packet size are shorter as in VOIP.
- Roll off factor = 20%.

The roll-off factor, α, is a measure of the excess bandwidth of the raised-cosine filter used for pulse-shaping in digital modulation. The closer the value is to 0, the narrower the filter is and the ISI (Interference Inter Symbol) is reduced. In the standard DVB S only a roll off factor of 0.35% is considered. With the new standard DVB S2, there is also the possibility of 0.30% and 0.20%.

6.4.8 TEST CAMPAIGN

6.4.8.1.1 Preliminary test-bed verification

This first phase consisted of a preliminary verification of the test bed without satellite segment (channel simulator and noise generator). It was divided in three steps:

1. Transmit Video using DVB-S2 with TS native end-to-end
2. Transmit Video using DVB-S2 with TS native on streaming side and IP on receiver side
3. Transmit Video using DVB-S2 on IP end-to-end

For all the 3 configurations, the behaviour of the test-bed in CCM mode with different level of scalability was tested. The streamed videos were 2D High Definition with a representative bitrate for the scalability layers defined in the frame of MUSCADE.

By the time of these test campaign the real MUSCADE content was not ready yet as well as it was not ready either the rendering/streaming software. This internship was executed in the first half of project MUSCADE duration. In this phase the reference architecture was still in process of development.

This is the reason of using 2D HD videos instead of the MUSCADE format video or different player softwares in each configuration.

The following tests were carried out in QPSK 4/5 and 8PSK 2/3.

- Transmit only one TS (Stereoscopic layer) with 1 ModCod in CCM mode
- Transmit two TS (Stereoscopic & ∆MVD2 layer) with 1 ModCod in CCM mode
- Transmit all TS (Stereoscopic, ∆MVD2, ∆MVD4 layer) with 1 ModCod in CCM mode

LAYER	ModCod	BITRATE (Mbps)
Stereo	QPSK 4/5 8PSK 2/3	13
∆MVD2	QPSK 4/5 8PSK 2/3	7
∆MVD4	QPSK 4/5 8PSK 2/3	17

In this case the channel simulator or the noise generator was not used. The architecture for the three configurations in the preliminary test campaign is described in figure 48, 49 and 50.

- Configuration 1: TS native end to end

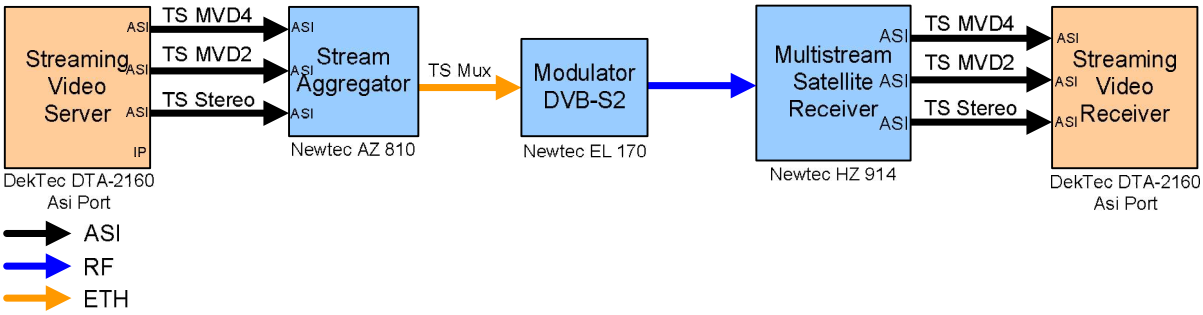


Figure 48 : Configuration 1

- Configuration 2: TS native on Gateway Side (emission side) and TS over IP on terminal Side

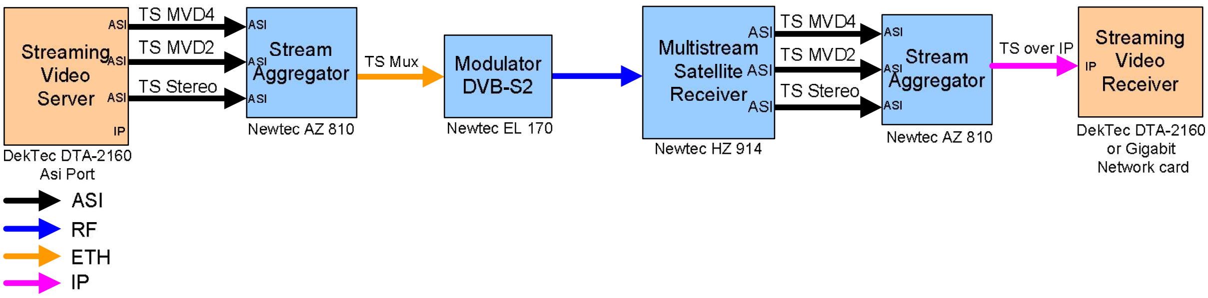


Figure 49 : Configuration 2

- Configuration 3: IP end to end using GSE encapsulation.

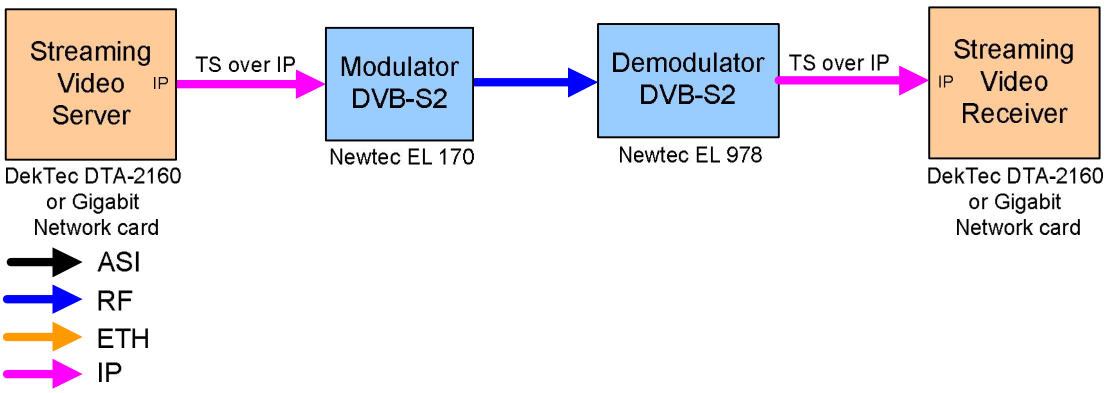


Figure 50 : Configuration 3

As it could be clearly seen in the test results, the test bed behaviour under the tests conditions is correct.

Figure 51 is an example graph obtained from the acquired metrics in this phase. Specifically it corresponds to configuration 3 when the three streams were sent through the chain. The ModCod was QPSK 4/5.

As we can see the E_s/N_0 is always over the threshold so it was demodulated and rendered perfectly.

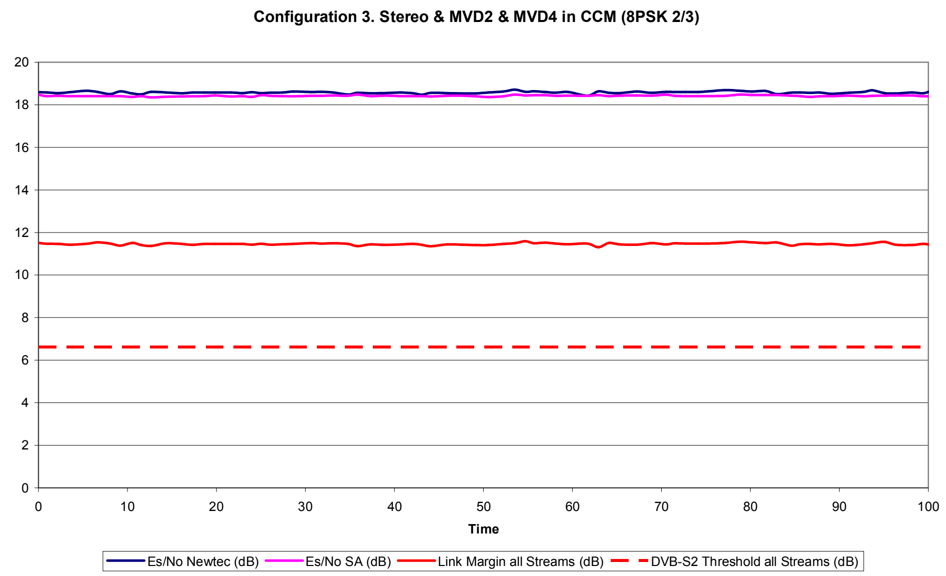


Figure 51 : Configuration 3. Signal level Stereo&ΔMVD2&ΔMVD4

The whole results from the preliminary tests can be found in Appendix II, for QPSK 4/5 and Appendix III for 8PSK 2/3.

6.4.8.1.2 Functional Verification

This phase consisted in verifying the switch over different MVC states with settings under different fading events.

Repetitive tests were carried out to assess the performance of MVC streams with different ModCods:

- Stereoscopic & ΔMVD2 & ΔMVD4: under favourable conditions, all three ModCods can be received.
- Stereoscopic & ΔMVD2 only received: fading conditions allowing only the Stereo and ΔMVD2 ModCods to be correctly received, ΔMVD4 ModCod being discarded.
- Stereoscopic only received: fading conditions allowing only the Stereo ModCod to be correctly received, ΔMVD4 & ΔMVD2 ModCods being discarded.

- No signal received: worst conditions, none of the ModCods can be recovered.

The MUSCADE ModCod choice was tested under the three configurations.

LAYER	ModCod	BITRATE (Mbps)
Stereo	QPSK 4/5	13
∆MVD2	8PSK 2/3	7
∆MVD4	16 APSK 3/4	17

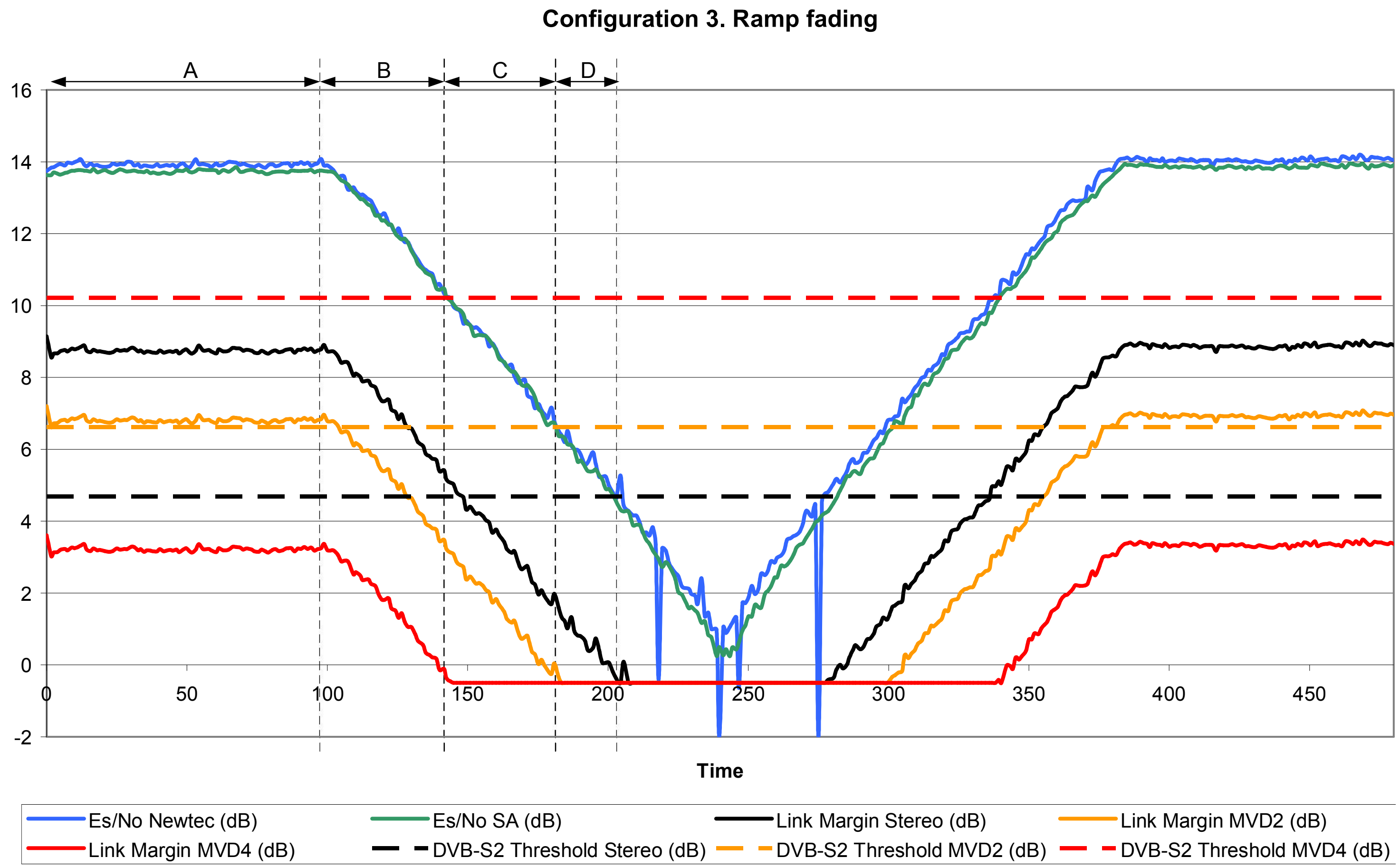
Figure 52 : Performance test. Defined ModCods

The post processed results are in the document called Appendix IV: performance test. A different ModCod choice was also tested in order to assure the flexibility of the testbed. Their results can be found in Appendix V.

LAYER	ModCod	BITRATE (Mbps)
Stereo	QPSK 5/6	13
∆MVD2	QPSK 8/9	7
∆MVD4	8 PSK 8/9	17

Figure 53 : Performance test. Optional ModCods

Figure 54 and 55 show an example of the post processed tests recovered through the test campaign. The first one corresponds to the signal level acquired from the graphical interface and the second one is the graph exports from RIO. It could be observed how the added noise affected progressively to each of the streams and how, in reception, the video in the screen was frozen until the signal level passed by the corresponding threshold. Hence, the conclusion was the correct behaviour of the proposed system.



A : Clear sky

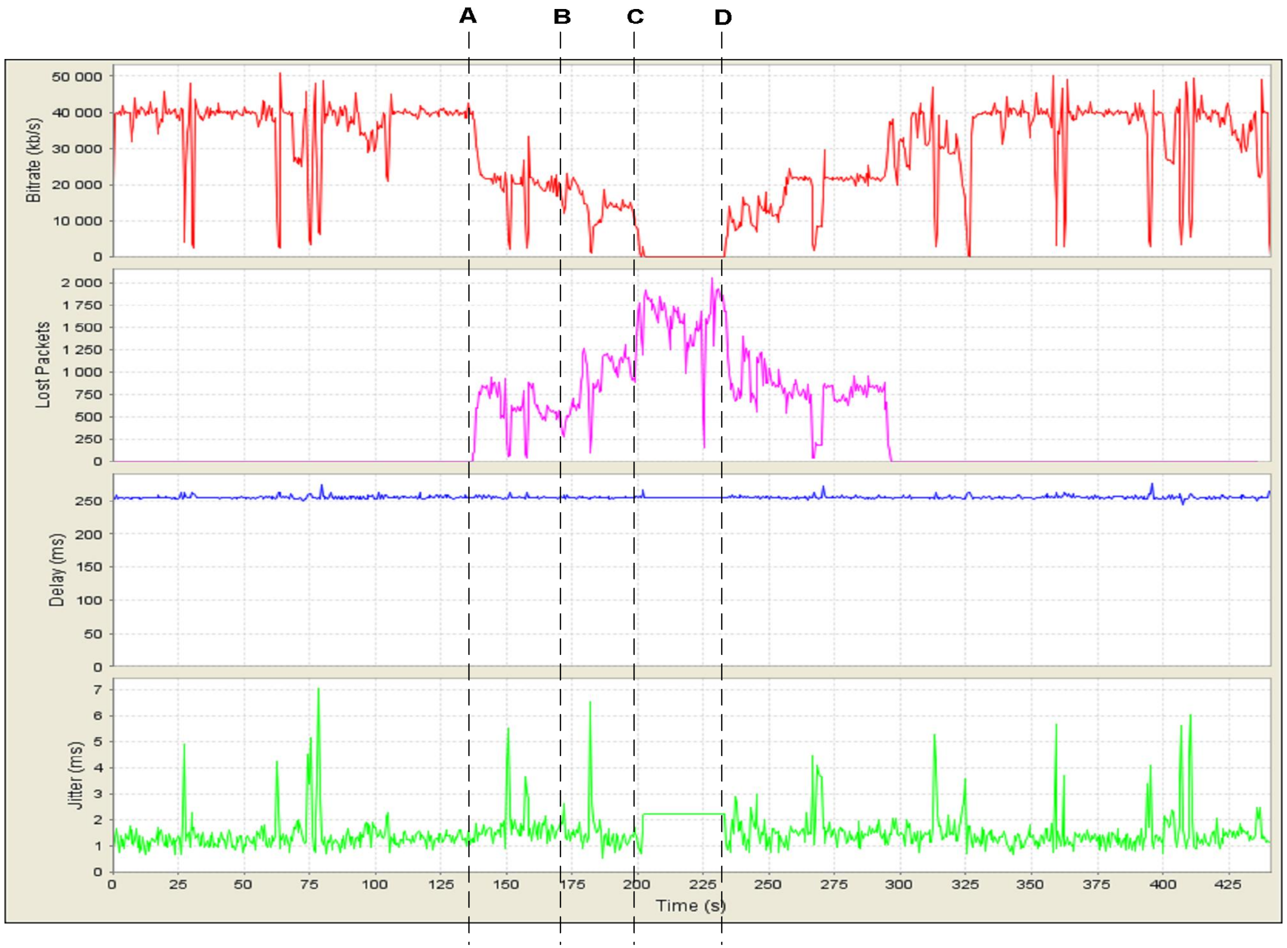
B : Fading begins but all streams can still be received

C: ΔMVD4 fades

D: ΔMVD2 fades

From D point none of the streams can be received

Figure 54: Configuration 3.Performance of MVC streams under fading event



A : ΔMVD4 stream fades

B : ΔMVD2 stream fades

C: Stereo stream fades

D: There is no video received

Figure 55: Configuration Metrics from RIO of MVC streams under fading event

7. CONCLUSIONS

The project that I carried out is proven very interesting and enriching for my professional experience.

During this internship, I had the opportunity to use the theoretical knowledge learnt during my formation at UPNA as transmission systems, network protocols, programming languages...

As the end of study project context (MUSCADE) is a very complex scenario, this allowed me to achieve very different new competences.

Satellite telecom Systems is a topic that I had never studied before and that I discover and found extremely interesting.

I have achieved a deep knowledge of satellite broadcast protocols by having the opportunity to discuss my questions with the person in charge of the GSE protocol workgroup.

Also, I have learnt several 3D technologies, from the content production to the rendering.

I have been witnessing the project evolution and how all the partners work together and that has allowed me to see the management process and his problems.

I am especially glad about the laboratory environment and the skills I could develop: programming on Labview, Telecommunications, get in contact directly with the equipment constructor, antenna pointing, devices configuration, communication protocols (GPIB, SNMP, Telnet)...

Working in a validation laboratory is very interesting, since the projects we carried out were always related to the latest technologies. The goal of BLUE lab is to validate the future satellite telecom applications, which allowed me to work on technologies such as 3D TV and where I had the possibility to participate in the future 3D TV standard format.

In addition of the many skills I learnt, I would like to point out the improvement in English and above all in French, due to the fact of working in a European project with partners of very different countries (Germany, France, England...).

I am really grateful for the welcome of the whole department which helped me having an overview of what working in a large company is. I had to take part in several meetings, dealing with deadlines and deliverables, which contributed to improve my organisational skills.

To sum up, this end of study project was a great experience, which helped to reinforce both my technical and human skills.

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